Technical Information Series

Generator Sets

Contents:
Engine
Electrical
Generator

KOHLER®
POWER SYSTEMS

ES–799

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ENGINE

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T I Series No. EN-1

TECHNICAL INFORMATION

KOHLER
ENGINES
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PRINCIPLES OF OPERATION AND ASSEMBLY

KOHLER CO. - KOHLER, WIS.

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CHAPTER ONE

Introduction

Down through the ages, man has progressed. His living standards improved as he learned to harness various forms of energy to do work for him.

His first accomplishment was to domesticate and train animals to carry materials and eventually to pull simple machines. Later man learned to get useful work from flowing water by means of water wheels. Today a portion of the electricity we use in homes and factories is developed from turbines and generators--an application of the age old water wheel principle.

Next came the use of the so-called fossil fuels, coal and oil. Changing the latent energy of coal and oil into useful mechanical work is accomplished in a variety of ways and we will discuss this in more detail later.

The sun is the original source of the energy in the fossil fuels. Coal and oil come from former living organisms and without the sun and its energy that life would not have been possible. The sun is still pouring down a tremendous amount of energy and only a very small fraction of it has ever been put to work. Scientists are studying ways of harnessing the energy from the sun, but so far, no big strides have been made.

Atomic energy is the newest basic source of energy to be exploited. This holds tremendous promise for the future and we can expect an improvement in our average standard of living as the result of peaceful use of atomic energy.

Of all the sources of energy indicated above, we obtain by far the greatest amount of work from coal and oil. The process of releasing energy from coal has reached its highest development in coal powered steam generating plants for providing electricity which has become an everyday necessity for all of us.

Steam engines operated from coal-fired boilers have also been used in providing useful work. However, they have many limitations and their use is decreasing. The reciprocating steam engine and steam turbines are classed as heat engines of the external combustion type. In other words, combustion of the fuel and release of the heat energy is accomplished at some external point of the engine.

In contrast to this, the release of energy from oil has reached a high state of development in the internal combustion engine. For example, the gas turbine type of engine such as used in jet aircraft is one form of internal combustion engine. But we will limit our discussion to the reciprocating or piston type internal combustion engine.

Historical Highlights

To get a good over-all understanding of any subject, it helps to have some knowledge of its past history and development. Briefly, here are some of the highlights of internal combustion engine history.

In 1824, Carnot, a Frenchman, described a theoretical heat engine process. This was an ideal process and is still recognized as the aim in the development of any engine. However, engineers to this date have been unable to develop the maximum conversion of heat energy into work as was described in Carnot's theory.

In 1838, Barnett, an Englishman, described a two stroke cycle engine. His description was also theoretical and although attempts were made to develop a working model, many difficulties were encountered.

During the Civil War period, Beau de Rochas, a Frenchman, set forth the principles of the four stroke cycle. However, it was not until 1876 that a German by the name of Otto built the first successful four stroke cycle engine. The gasoline engine down to this day is often called an Otto cycle engine.

In 1892, another German, Rudolph Diesel, proposed an engine in which the air and fuel mixture would be ignited by the heat developed during rapid compression.

The development of engines in the 19th century was influenced by the need for pumping water from the early coal mines. Man's usage of coal was accelerating and it became necessary to go deeper into the ground for more coal. Hand powered pumps became impractical as the volume of water to be handled increased. The first engines developed for the mines were huge machines of small power output.

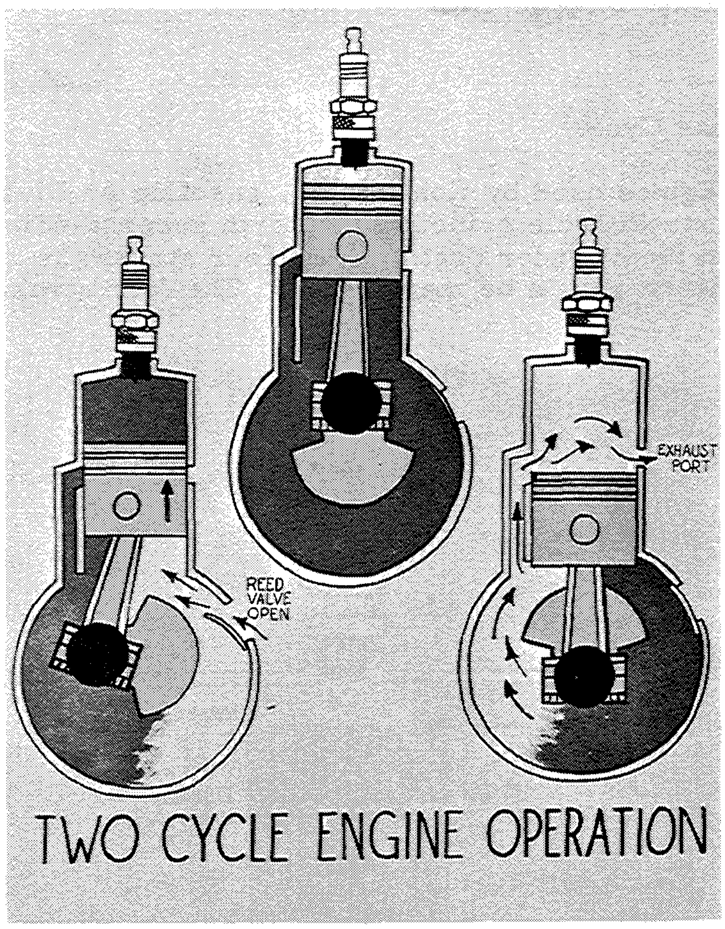


Figure 1.1

Two Stroke Cycle.

Engines are described by the number of strokes required by the piston to complete one operating cycle. A stroke is defined as movement of the piston from one end of its travel to the other. It may be either toward the crankshaft or away from it.

In the two stroke cycle engine or two cycle engine, as shortened in every day usage, one operating cycle is completed for every two strokes of the piston or one revolution of the crankshaft. Air is usually introduced through holes or ports in the cylinder wall.

As the piston moves up, these ports are closed and the charge is compressed. The fuel and air mixture is ignited when the piston is near the top dead center and the rapid burning and expansion of the gases forces the piston downward again. Part way down in its travel, other ports are opened allowing the burned gases to exhaust and clean the cylinder in preparation for the next incoming charge. Two cycle operation is used today in both gasoline and Diesel engines.

Four Stroke Cycle

All engines used by Kohler Co., gasoline or Diesel, operate on a four strokecycle principle. A firm understanding of what happens in the cylinder during these four strokes is important. This sequence should be memorized. The four strokes are as follows:

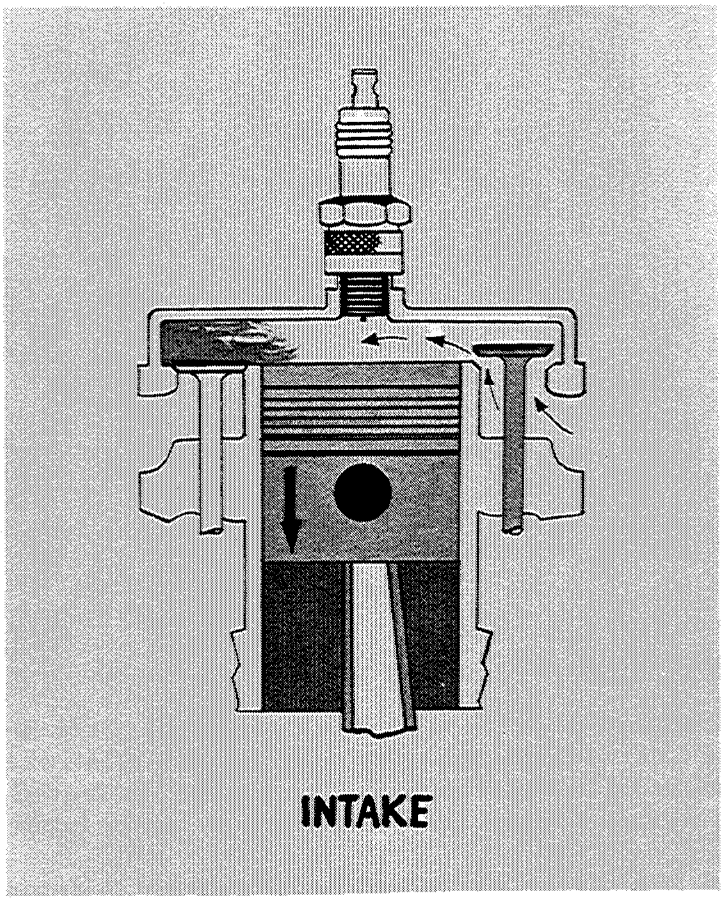


Figure 1.2

a. Intake Stroke -- At the beginning of this stroke, the piston is at the position closest to the cylinder head, thereby filling the cylinder space and reducing the open volume of the cylinder and combustion chamber to a minimum. As the piston moves toward the crankshaft and with the intake valve open, air is drawn into the cylinder.

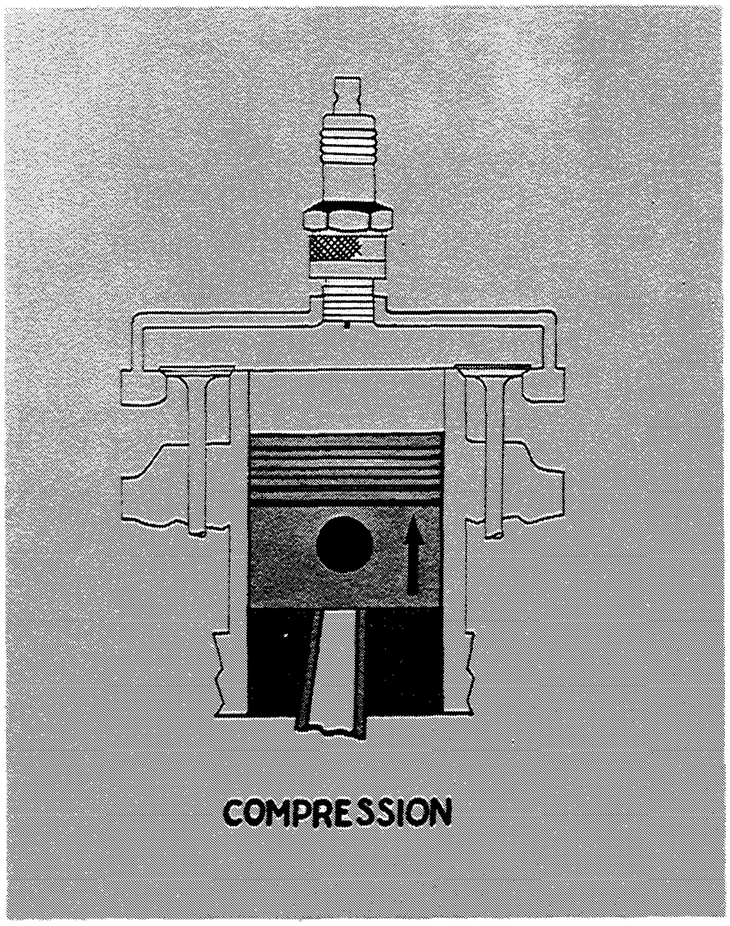


Figure 1.3

b. Compression Stroke -- With air in the cylinder and the piston at the bottom or at the point closest to the crankshaft, the intake valve closes. Since there is no other opening, the air in the cylinder is compressed as the piston travels toward the top of the cylinder. In the case of the gasoline engine, the fuel is already mixed with the air as it is drawn into the cylinder. In the Diesel engine, fuel is injected into the cylinder toward the end of the compression stroke. Just before it reaches top dead center, or the point where it is farthest from the crankshaft, the charge is ignited. This is true of both gasoline and Diesel engines.

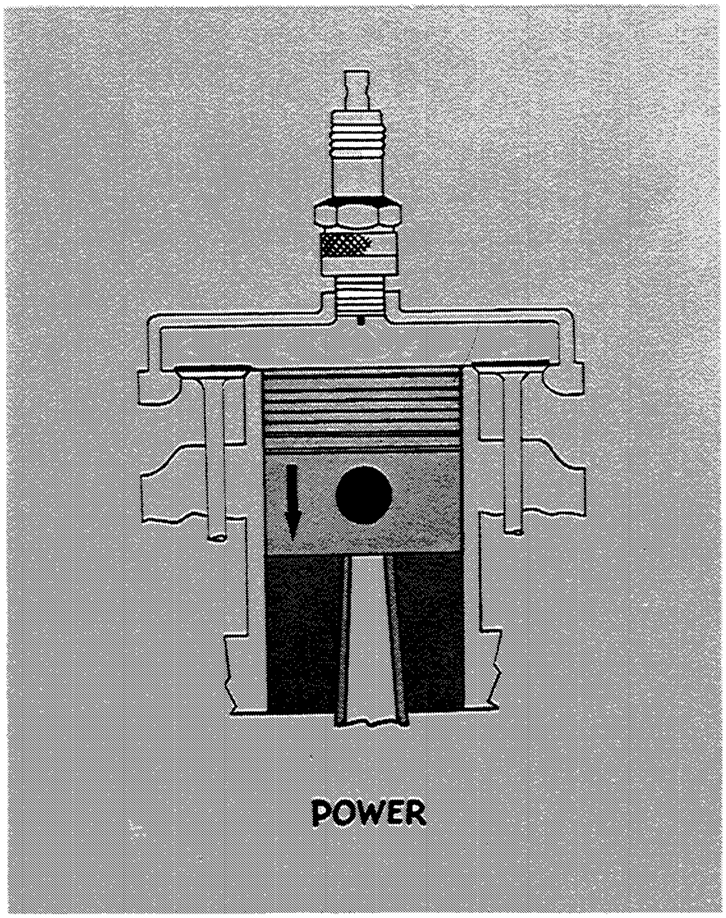


Figure 1.4

c. Power Stroke -- As the fuel burns in the cylinder, heat is released causing a rapid pressure buildup as the gases expand. This pressure on the piston causes it to move downward, through the mechanism of the connecting rod and crankshaft delivering useful energy to the rotating crankshaft.

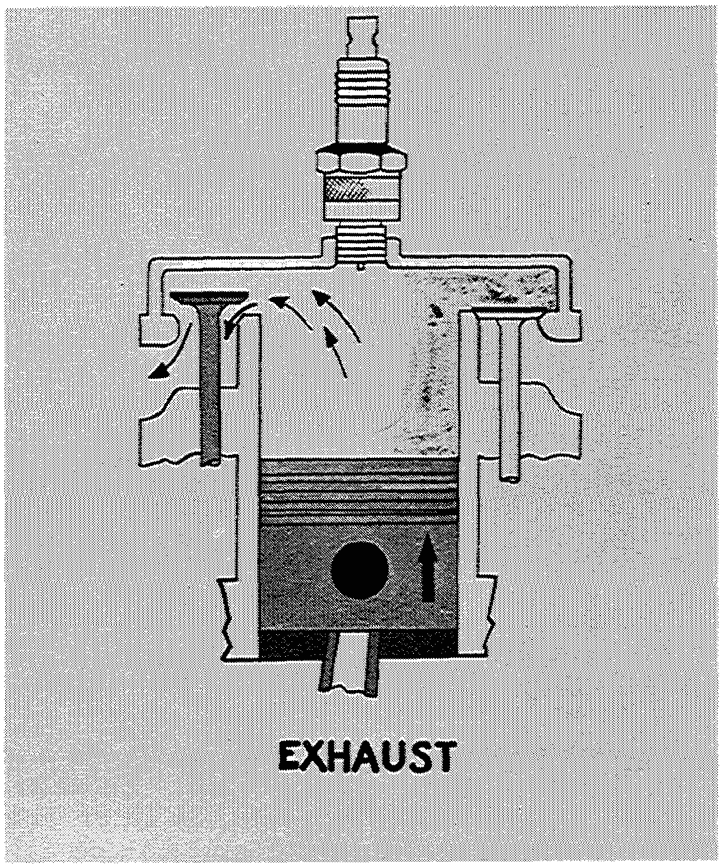


Figure 1.5

d. Exhaust Stroke -- At the end of the previous power stroke, the exhaust valve opens, and as the piston moves upward the exhaust is forced out of the cylinder. The exhaust valve closes at the end of this stroke and the engine is ready to repeat the cycle.

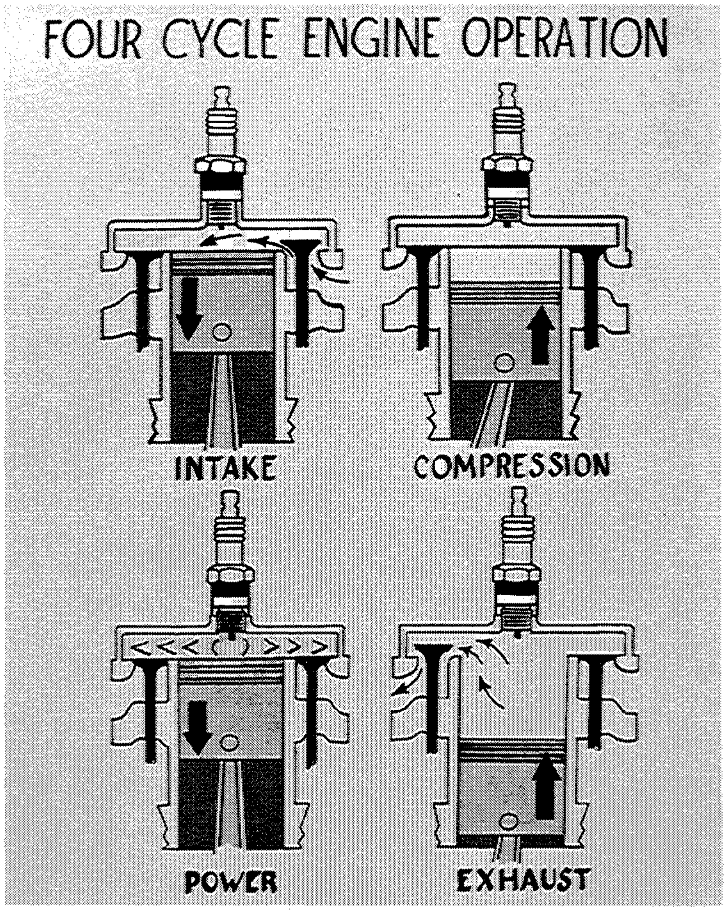


Figure 1.6

Engine Compression Factors.

Displacement of an engine in cubic inches is a measure of the size, or potential power of the engine. By definition, it is the volume which the piston displaces. In other words, the displacement for a single cylinder engine can be calculated as follows. Piston area multiplied by the length of stroke or $\frac{\pi}{4}$ X (Cylinder bore)^2 X Stroke. For a multi-cylinder engine, this quantity is determined for one cylinder and simply multiplied by the number of cylinders in the engine.

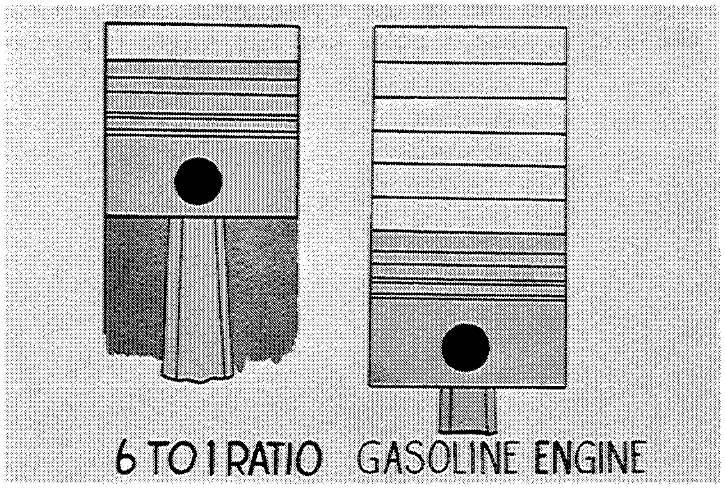


Figure 1.7

Another engine feature is compression ratio. In every engine there is a small volume of air around the heads of the valves and in the contours of the combustion chamber, even when the piston is at top dead center. This is called the clearance volume. This volume plus the piston displacement is the total volume. Compression ratio is defined as the total volume divided by the clearance volume -- or displacement plus clearance volume divided by clearance volume. As a formula it may be expressed:

$$C.R. = \frac{V_{Total}}{V_{Clearance}} = \frac{V_{Displ.} + V_{Clear.}}{V_{Clearance}}$$

The amount of power an engine develops is directly related to the degree of compression achieved in the cylinder. The efficiency with which the fuel is burned is also higher with a high degree of compression. This is the reason for the trend in automotive engines toward higher compression ratios.

Progress toward higher compression ratios is limited by the burning characteristics of the fuel. In overhead valve engines, where the valves are normally directly over the engine, there are no limitations in design for achieving a high compression ratio because it is easy to design such an engine with a small clearance volume. With "L" head engines, such as our air cooled models, it is not easy to keep the clearance volume small and therefore we are limited to compression ratios in the range of 6 to 6.5.

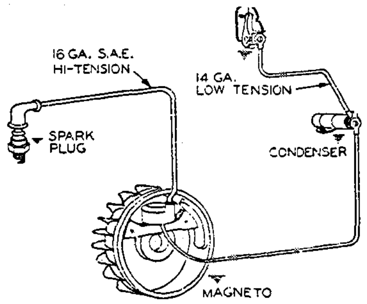
The engine features which hold the compression and power stroke pressures in the cylinder are the valves and seats, the cylinder head gasket and the piston rings. To get proper power from a given engine and to get proper starting characteristics, there can be no leakage through any of these parts.

In Diesel engines the pressures in the cylinder during compression and combustion range from 700 to 1200 psi. as compared with 300 to 500 psi. in gasoline engines. Compression ratios in Diesel engines range from 15:1 to 20:1 as compared with 5.5:1 to 10.5:1 for gasoline engines.

As air is compressed in the Diesel engine cylinder, its temperature increases. If this is done very rapidly, there is insufficient time for this heat to escape to the surrounding cylinder walls. With a high compression ratio and rapid compression of the air, temperatures can be reached which will ignite the fuel when it is injected into the cylinder. This is known as compression ignition and is the characteristic operating principle of Diesel engines.

Spark Ignition.

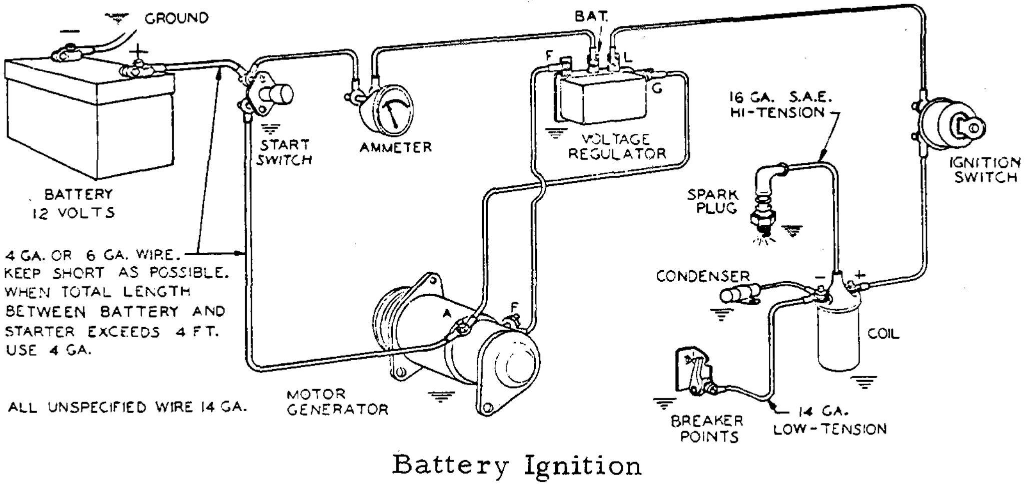
In gasoline engines the fuel and air mixture is ignited by means of an electric spark. The spark jumps from one spark plug electrode to the other in the combustion chamber. The electricity for that spark must be of high voltage in order to jump the gap, but can be of relatively small current flow.



Magneto Ignition
Figure 1.8

The high voltage is produced in a coil. The coil has two windings. Current is flowed at low voltage through the primary winding of the coil which is relatively heavy wire and few turns. The charge of current in this winding causes a high voltage, low amperage current in the secondary winding. This is true of both magneto and battery ignition systems. The current for the primary winding of a battery ignition system comes from the battery.

In a magneto system this primary current is generated by a rotating permanent magnet which induces current in a near-by iron core and from there into the primary winding of the coil. Interruption of the primary current by means of breaker points on both battery and magneto systems causes a rapid change in the coil and thereby produces the high voltage necessary at the spark plug. This voltage may run as high as 20,000 volts with approximately 7,000 being required for initial starting.



Battery Ignition
Figure 1.9

Timing of the spark is essential to obtain maximum power from the engine. The point at which the spark should occur will vary with the speed and the design of the engine. Under running conditions, the spark should occur before the piston reaches top dead center so that the burning of the fuel has started before the piston begins its downward stroke. Maximum pressure is necessary to get the maximum work from the rapidly expanding gases.

Combustion of The Fuel & Air Mixture.

Many people think of engine combustion as an explosion or simultaneous burning of all parts of the fuel and air mixture. This is incorrect.

The type of combustion desired in an engine is a progressive burning of the fuel and air mixture. The flame starts at the spark plug and travels in all directions from that point. It can be influenced by extreme turbulence of the fuel and air mixture. Researchers have actually photographed this flame front at various stages as it proceeds across the combustion chamber.

As the flame travels, heat is generated and gaseous products of combustion are released. A rapid buildup of pressure results. This pressure is also built up on the forward side of the flame in the fuel and air mixture which the flame has not yet reached. The pressure and temperature of this forward part of the mixture may reach the point where it is ignited by itself, similar to Diesel ignition.

A very rapid buildup of temperature and pressure is produced and combustion becomes uncontrolled. Ignition of the charge in front of the flame front is known as auto-ignition or detonation. Another form of uncontrolled combustion is caused by some spot in the cylinder remaining hot enough after the exhaust stroke to ignite the incoming mixture before the normal spark ignition. This causes an abnormal buildup of pressure, rough sounding operation and loss of power. It is known as pre-ignition. All such forms of uncontrolled combustion result in excessive pressures on rings, pistons, cylinder heads and bearings and loss of power output. Extended operation under such conditions will lead to mechanical failure of some part of the engine.

The air and fuel mixture in a gasoline engine must be within certain limits in order to ignite and burn. The extreme limits of the ratio of air to fuel weights are approximately 7:1 for a rich mixture and 20:1 for a lean mixture. For our engines this range is apt to be much narrower and operation will usually fall in the range from 10.5:1 to 14:1. Maximum power is usually obtained around 13:1 air fuel ratio.

In a Diesel engine, combustion starts shortly after the beginning of fuel injection. The fuel is sprayed into the combustion chamber at a carefully calibrated rate. The amount of power the engine will develop is determined by the length of time the fuel is injected. The pumps are so constructed that this time is varied according to the setting of the governor. Where the governor on a gasoline engine varies the position of the carburetor throttle, the governor on a Diesel engine varies the length of time that fuel is sprayed into the cylinder.

Valve Timing & Lift.

Referring again to the four basic strokes in a four stroke cycle engine, we must provide for the opening of the intake valve before we start the intake stroke. During the first part of the valve opening, movement is small in comparison with crank angle travel. In order to have the valve open a suitable amount by the time the piston starts drawing air into the cylinder, we must start the opening of the intake valve before the piston reaches top dead center. Then we must open it as fast as mechanically possible and far enough to provide the minimum resistance to flow of air through the valve port.

When the piston approaches bottom dead center, air is being drawn in at a rapid rate. Because the air has inertia we can keep the intake valve open somewhat beyond bottom dead center and the momentum of the air in the intake system tends to pack more air into the cylinder. The ideal place to close the intake valve would be at the point where air movement through the intake valve starts to reverse itself. In most high speed engines in use today, this point will range from 35° to 65° of crank travel beyond bottom dead center.

Intake valve closing, therefore, is always after bottom dead center and is specified in those terms. Both valves are closed during the compression stroke and the early part of the power stroke. During the power stroke, some of the energy from the expanding gases is sacrificed to make sure that the exhaust gases are completely cleared from the cylinder in preparation for the next intake stroke. It is common practice to open the exhaust valve before bottom center for intake valve opening.

Cams are designed to provide: (1) a clearance of a few thousandths of an inch during a part of the cycle when the valves must be closed, (2) a ramp for engaging the valve and starting its lift, (3) a portion to accelerate the valve to maximum opening velocity, (4) a section to decelerate it to a stop at the cam nose, and (5) the other half of the cam lobe which closes the valve again through the same sequence but in reverse.

The intake manifold, valve ports and throat area of the combustion chamber must be of such size and shape that air may flow through with minimum restriction. Accumulations of carbon or lead deposits in any of these areas will immediately decrease the maximum power.

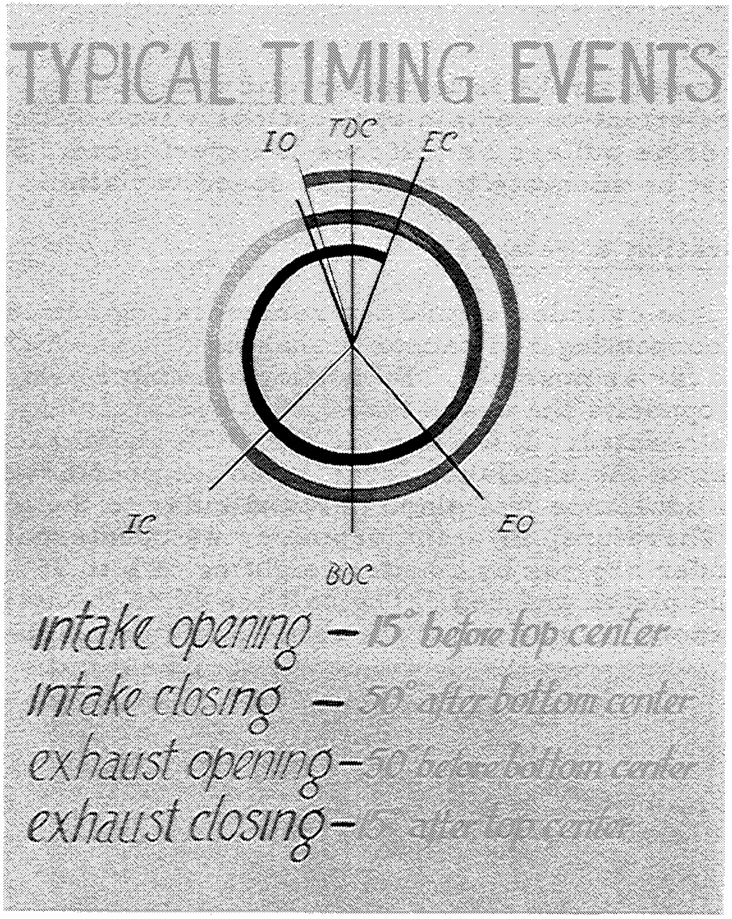


Figure 1.10

The intake valve ordinarily does not achieve excessively high temperatures. It is cooled by the incoming air and fuel mixture. The exhaust valve, however, receives the full blast of the exhaust gases and can dissipate only through the valve guide and valve seat. Ordinarily at wide open throttle the exhaust valve will be red hot. You can see it through the exhaust port. To withstand such temperatures, the valve head must be of stainless steel or it will corrode very rapidly. For extreme conditions, the face of the valve must also be coated with stellite to provide sufficient hardness and corrosion resistance. Valve rotators aid in providing good valve life under heavy load conditions.

Flywheel.

An engine produces its power during the power stroke only. Therefore, there must be sufficient momentum built into the engine to carry it through the other three strokes without injurious loss of speed. This function is performed by the flywheel.

Ordinarily our flywheels are designed somewhat on the light side to reduce engine weight. We depend on the equipment being driven by the engine for part of the flywheel action. Even at best, there is always some slowing down of the engine between power strokes. This slowing down and subsequent speeding up during the power stroke is termed cyclic irregularity. This becomes important on certain applications where difficulty with couplings, drive pulleys or clutches is experienced. Such components must be adequate to take this speed variation.

Engine Vibration & Balance.

In a single cylinder engine the reciprocating action of the piston and connecting rod causes a shaking action which must be balanced as far as possible. By putting a counter-weight on the crankshaft opposite the crank throw, the reciprocating unbalance can be counteracted. If we provide for 100% counteraction in the direction of the unbalance force, then the counterweight sets up an equal unbalance in a plane perpendicular to the axis of the cylinder. Therefore, as a compromise, we counterbalance single cylinder engines by counterweighting 50% to 75% of the weight of the piston and rod. The balance of multi-cylinder engines is more complex, but the same basic principles apply.

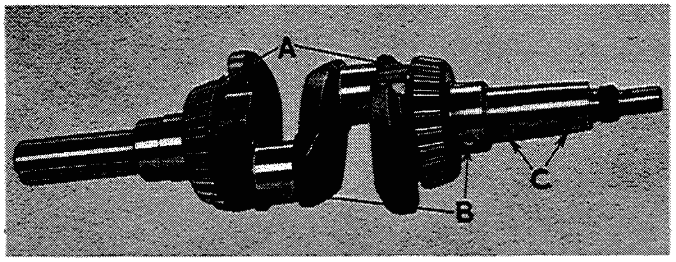


Figure 1.11

Cooling.

As mentioned previously, cooling of valves is a critical part of engine performance. The exhaust valve transfers its heat through the stem and into the guide which in turn conducts it to the outside of the cylinder block. Some valve heat is also transferred through the seating face to the valve seat insert and from there to the surrounding portion of the block.

Providing adequate cooling air or cooling water, depending on the type of engine, to that portion of a cylinder block is of prime importance. The cylinder head contains most of the combustion chamber and becomes hot during the power stroke. It must be cooled so that the head itself retains its physical strength and shape and to prevent the hot spots from developing in the combustion chamber, causing pre-ignition. The piston is cooled, to some extent, by oil splashing against the underside of it. The piston rings transmit heat from the piston to the cylinder walls. The heat picked up by the cylinder walls, plus that resulting from direct exposure to the combustion flame, must be disposed of by air forced through cooling fins around the cylinder of an air-cooled engine or by a water jacket on the water cooled engines.

If the cylinder is inadequately cooled, the oil temperature tends to run high and will break down in the ring section causing ring sticking and excessive carbon and varnish buildup. Providing a blower for cooling air requirements of an engine, whether it be air cooled or radiator cooled, ordinarily takes from 5% to 10% of the available engine power.

Lubrication.

A very thin film of oil is adequate to lubricate cylinder walls. The rings are designed to scrape excess oil from the walls and prevent passage of excessive amounts to the combustion chamber. Gasoline and Diesel engines are lubricated to some extent on the upper portion of the cylinder by the fuel itself. When operating on gaseous fuels, such as propane and natural gas, some engines run so dry that a top oiler must be added for providing sufficient lubrication for the upper end of the piston travel.

The connecting rod bearings are critical parts of the engine. High and varying pressures and high rotating speeds make the lubrication job at this point important.

In splash lubricated engines, such as our smaller one cylinder engines, the oil must find its way into the bearing surface through drilled holes or grooves after being picked up as droplets during the rotation of the crank and connecting rod. The simplicity of a splash lubrication system is desirable on smaller engines in order to keep costs to a minimum.

On our larger engines, such as the K331 and K662, we use a gear type oil pump to force oil through the drilled passages to various spots in the cylinder block where bearings, including the connecting rod bearing, are present. We provide an oil transfer sleeve between the cylinder block and the crankshaft in order to get oil into the shaft. From there it goes through drilled passages to the crank pin journals where they feed the connecting rod bearings. Pressure lubrication to the connecting rod bearings is advantageous in providing a more positive supply and definite oil circulation through the bearings. A certain amount of cooling of the bearings is accomplished with the oil.

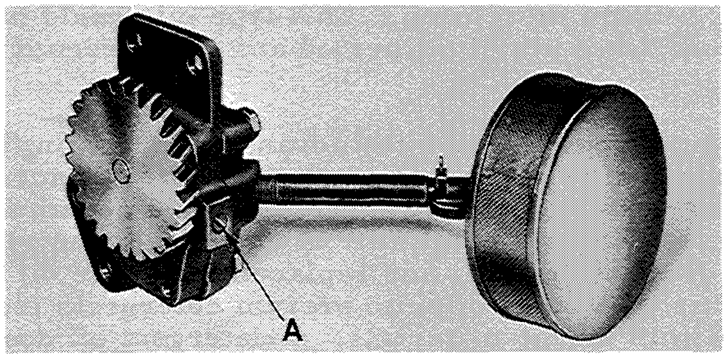


Figure 1. 12

The lubrication of sleeve type main bearings such as used on the L600 and the larger purchased engines is provided by oil pumps and drilled passages, the same as for the rod bearings. An anti-friction bearing, such as the ball and roller bearings used in our smaller engines, needs very little lubrication. In fact, it is undesirable to allow excessive amounts of oil to pass through the bearings.

Camshafts, timing gears, governor, magneto and oil pump drive gears are very lightly loaded and receive adequate lubrication just from oil thrown off from other parts in their vicinity. The camshaft bushings on larger engines receive pressure lubrication, but it is not at all critical. Lubrication around the flyweights of a governor must be moderate and excessive amounts of oil will adversely affect the action of the flyweights. Reduction gears are highly stressed and must be lubricated very carefully.

OIL CHART
API Service MS

Air Temperature	Single Viscosity Oil	Multiple Viscosity Oil
Above 30° F.	SAE 30	
30° - 0° F.	SAE 10	SAE 10W-30
Below 0° F.		SAE 5W-20

The question frequently comes up whether we should use a straight mineral oil or one which includes detergents. Normally we recommend the heavy duty grade which always includes detergents. During initial run-in periods (in field service) on engines equipped with an oil pump there may be some advantage in using a straight run mineral oil. Any particles which are worn off surfaces during the run-in period would then have a tendency to accumulate in the oil sump rather than being continually pumped through the engine bearings. In a splash lubricated engine where the oil in the sump is continually churned up, there is no advantage in using a straight mineral type oil for run-in. The run-in on our test line is a different matter. The oil used maintains a fairly thin film allowing surfaces to rub off any high spots, yet preventing seizure or scoring. This type oil should not be used on heavy load for a very long period and is not recommended for field use.

Detergent type oils have the advantage of keeping valve stems, rings and cylinder walls relatively free of accumulations of carbon or varnish. It also prevents sludge accumulations in the crankcase and keeps that sort of material in suspension in the oil. Frequent draining and replacement of the oil is still necessary as with other oils, to prevent detergents from becoming overloaded with sludge materials. If detergent oil does become completely loaded it may suddenly become a jelly-like mass making further operation of the engine impossible. The operator seldom realizes that the oil is in this condition and it frequently results in burned out bearings.

There is no substitute for periodic draining and replacement of the oil supply.

There are a number of special additives on the market. Although some of these materials have merit for certain conditions on some engines, we believe that with adequate maintenance and proper engine use, special additives are unnecessary.

Fuels.

Gasoline. Petroleum is a mixture of a large number of different hydrocarbons -- materials composed of hydrogen and carbon. These two elements may be combined in a wide variety of ways with each combination being quite stable and having its own individual boiling point and ignition point. If you were to heat a quantity of gasoline, you would find that a certain portion of it would boil off at approximately 100° F and other portions would boil off at intermediate points between that temperature and 250° to 300° F. This characteristic varies quite widely, depending on how the gasoline was refined. The characteristic of a varying boiling and ignition point is the principle reason for gasoline being a superior engine fuel. Alcohol, on the other hand, is a single chemical compound with a single boiling and ignition point for a given pressure. When alcohol is used as a fuel it has a tendency to burn too rapidly and uncontrollably. The basic chemistry of gasoline allows it to burn in a controlled sequence according to the temperature and pressure required for the various hydrocarbon materials.

Octane is one of the hydrocarbon compounds in gasoline. It has superior anti-knock characteristics and at one time was considered the ideal or nearly perfect engine fuel. It was therefore used as a basis for comparing the anti-knock performance of various gasolines. The octane rating has developed from this concept and two different methods of rating gasolines are in current usage; the research method and motor method. The research method is the original one and is always the higher of the two ratings.

Tetraethyl lead also has excellent anti-knock characteristics. In developing engines of increasing efficiency and more power from a smaller size, it has been necessary to design engines of ever increasing compression ratios. It was impossible or uneconomical to refine gasolines which would perform without knock in these high compression engines unless tetraethyl lead was added to the gasoline. Certain other compounds are formed by the action of the lead and the fuel during engine combustion. Some of these compounds deposit on the walls of the combustion chamber, the top of the piston and the valves. Most of the deposit buildup observed in such areas is the direct result of the lead in the fuel.

The question is frequently asked whether we can use white gas in Kohler engines. It may be possible under light load conditions, but normally speaking we must discourage its use because knocking occurs under load. Most white gas has a low octane rating. A rating of at least 75 is recommended for Kohler engines. Most regular grades of gasoline today are 90 octane or better.

When gasoline is stored for any extended period of time, certain portions of it tend to oxidize and thereby form a heavy gummy substance. This gum can plug up the tiny holes in carburetors and thereby cause unsatisfactory engine performance. The best way to avoid this condition is to avoid lengthy storage of the gasoline.

Gaseous fuel. Engines can be made to run on gaseous fuels such as propane, butane, natural or manufactured gas. The energy potential of these fuels is as follows:

Propane-Butane	--	2600 - 3300 BTU/cu. ft.
Natural Gas	--	1000 BTU/cu. ft.
Manufactured Gas	--	400 - 600 BTU/cu. ft.

Natural gas, being roughly 1/3 the BTU value of propane, must be supplied in three times the volume required for propane for a given engine power output. Manufactured gas is always quite low on BTU value and is sometimes modified or enriched with natural gas. It is important to know which gas is to be used when furnishing carburetion equipment for a specific job. The low value gases require regulators, lines, etc. which will supply many times the volume of propane gas for a given power output required.

One big advantage of gaseous fuels is their freedom from tetraethyl lead. Deposits in the combustion chamber are kept to a minimum.

Diesel fuel. The Diesel fuel is simply specified as grade #1 and #2. Grade #1 is generally a lighter weight or lower viscosity.

Cetane rating is the quality of the fuel which compares with octane rating in gasoline. The minimum cetane rating is usually considered 45. In low temperatures, it is quite common for Diesel fuels to become jelly-like. The point at which they cease being a liquid is known as the pour point. This fuel quality should be watched carefully in temperatures of 20° F or lower.

Engine Power & Power Rating.

To accurately measure the amount of power an engine can produce, a dynamometer must be used. There are various types available, the simplest of which is probably the water dynamometer. One which we use extensively in our laboratory is a DC generator with special type cradle mounting. The generator is supported on ball bearings and the frame is free to rotate on these bearings supports through a small range. An arm extends out from the generator frame and an accurate scale is connected to that arm for measuring the amount of force exerted at that point. When the engine is rotating the generator armature, we may vary the amount of load on the engine by varying the excitation of the generator and thereby vary the amount of electricity it produces.

The amount of torque or twisting effort exerted by the engine crankshaft on the generator armature is identical to and may be measured by the torque at the arm extending from the generator frame. By knowing the distance from the center of the generator to the point at which the force on the arm is measured a constant can be worked out for use in calculating power. The constant times the force measured on the scale times the RPM of the engine gives a reading of horsepower which is completely independent of the electrical efficiency of the generator and is derived simply from mechanical measurement of the torque exerted by the engine.

The power an engine will produce is affected by temperature, barometric pressure and a very small degree by humidity. Dynamometer ratings for engines are always corrected to so-called standard conditions of 60° F and sea level barometric pressure. Rating procedures have been standardized for engine manufacturers by the Society of Automotive Engineers (SAE) and the Internal Combustion Engine Institute (ICEI). We follow these procedures when rating our engines for power.

Remember, altitude affects power by approximately a 3% loss for every 1000 feet of elevation above sea level. Thus, at Denver, Colorado, which is at 5000 feet above sea level, engines have lost 15% of their maximum power.

Temperature affects power approximately 1% for every 10° variation in temperature from 60°. Therefore, at 100° F which is 40° above the standard rating temperature maximum power would be 4% lower than the standard rating.

Humidity has a very small effect on engine power. Popular opinion attributes much better operation of automobile engines during rainy weather. There are other factors which produce this illusion.

To show more graphically the relationship of these various factors, the following power correction formula is shown. This is the one used in correcting observed dynamometer readings.

$$BHP_{Corrected} = BHP_{Observed} \times \left(\frac{29.92}{Bar. - e_{Observed}}\right) \sqrt{\left(\frac{460 + Temp._{Actual}}{520}\right)}$$

Where e = vapor pressure obtained from charts after measuring wet and dry bulb temperatures.

It is general practice in this country to rate engines for sales purposes at the maximum amount of power they will produce. The sales specification sheets show a maximum power curve which can be obtained from a laboratory engine and with readings corrected to the standard conditions indicated above. If an engine were operated at this power continuously, its life would be rather short. On applications where the number of hours used is moderate, it is allowable to use power up to approximately 85% of the maximum amount and still get suitable life from the engine. A curve representing 85% of the maximum power curve is termed the intermittent rating. For continuous operation, we recommend that power be limited to 75% of the maximum power. We may advise even lower power output if, besides continuous operation, the application requires extremely long life. In general, the amount of load on the engine is more important than its speed in promoting exceptionally long life. However, low speed and light load is always best.

Engine Torque & Torque Curves.

As indicated before, describing dynamometer measurement of power, the power can be calculated from the torque if the speed is known or, conversely, the torque can be calculated from the known power reading. The torque curves we show on our specification sheets are always calculated from the power curves, and, therefore, are closely related to power. The shape of the torque curve is important on many applications. It is desirable to have a torque curve which is fairly flat or gently drooping toward the low end of the speed range. At the high end of the speed range it should be approximately 10% lower than medium range in order to provide an increase in torque as the engine is pulled down in speed on heavy load. This gives the engine a good lugging characteristic. The torque curve is modified by modifying valve timing in the initial development of the engine.

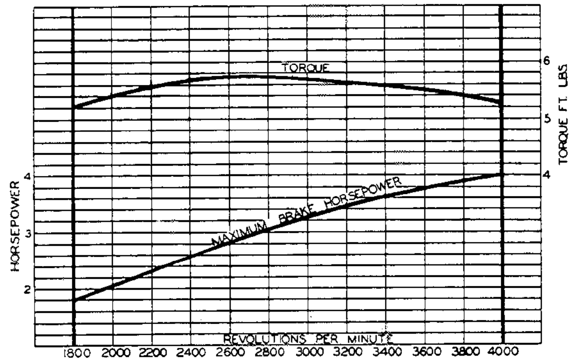


Figure 1. 13

Types of Drives.

Power is taken from engines either by means of coupling directly to the crankshaft or by means of belt and pulley or chain and sprocket types of drive. If the equipment is direct coupled, the type of coupling and the alignment between the engine shaft and equipment shaft is important. If it is direct coupled with a solid coupling, alignment must be kept within a few thousandths of an inch. If a flexible type coupling is used, some additional misalignment can be allowed but if the misalignment is excessive and the coupling flexes to a considerable degree it is possible to lose much engine power right in the coupling.

When using "V" belt drives it is important that the size of the driving pulley and belt be suitable for the amount of power being transmitted. Many times it is necessary to use several "V" belts on the larger engines. When using a chain and sprocket type of drive, the tension on the chain is of importance because there may be a whipping action due to the engine speed variation from one cycle to the next. This may be injurious to both engine and equipment, if not properly provided for. "V" belts, with their ability to stretch, act somewhat as a shock absorber and are much easier on the engines.

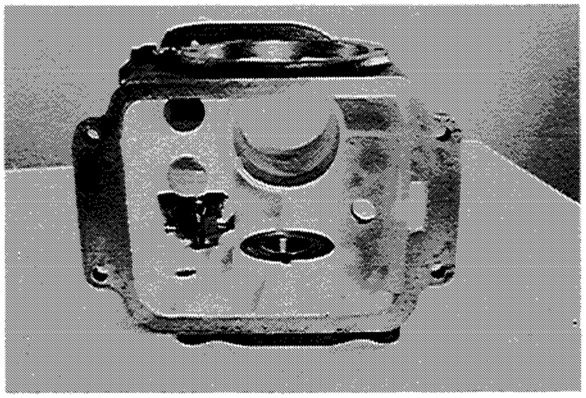
Sometimes customers require a clutch between the engine and their equipment. We can supply lever operated disc type clutches and customers frequently purchase separate centrifugal type clutches.

There is also the requirement for a reduction in rotating speed. We supply gear reductions for this purpose. In working with such a gear reduction it should always be kept in mind that engine torque is multiplied by the same ratio as the speed is reduced. With a chain and sprocket type drive on a gear reduction, firmness of engine mounting becomes essential. If the chain is directed out to the side of the engine, the torque tends to twist the engine and may show up as loosened mounting cap screws or loose screws between the engine block and base. We can also supply combination clutch and reduction units on our larger engines.

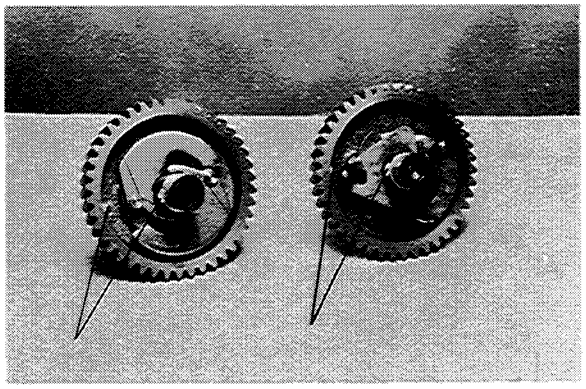
CHAPTER TWO

ASSEMBLY OF KOHLER SINGLE CYLINDER ENGINES

These illustrations show the sequence of assembly of a single cylinder Kohler engine. The engine used here was specially prepared to better show the components. When actual work is being performed, always refer to the Engine Service Manual.

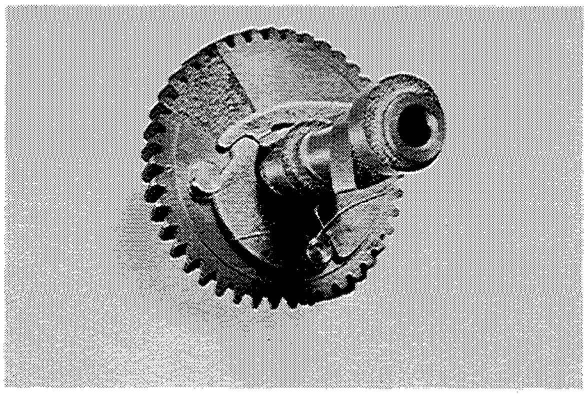


1. Install the rear main ball bearing by pressing it into the cast iron cylinder block. If bearing is shielded place shield facing inside. Install internal governor parts by referring to service manual. Install tappets.

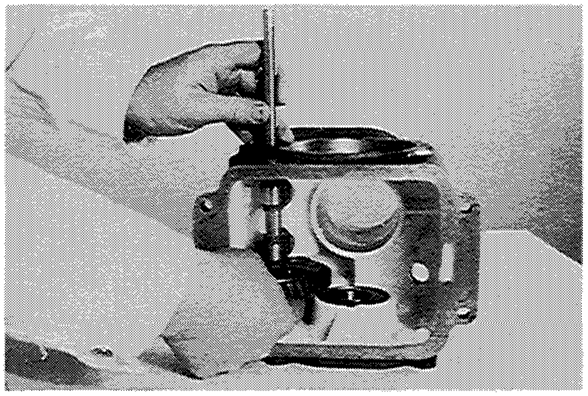


2. This illustration shows two types of spark advance systems. The standard mechanism is shown on the left and the magneto alternator spark advance system is shown on the right. Be sure the spark timing marks on cam and spark advance side of camshaft gear coincide. Marks on gears and shafts may be seen on the left-hand side of each component.

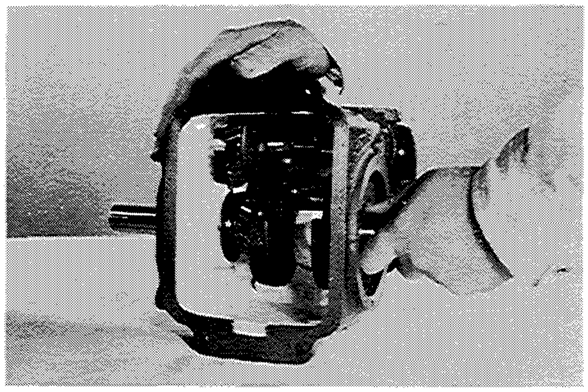
3. The Automatic Compression Release camshaft is shown in this illustration. This assembly has a cam lever which raises the exhaust valve slightly during the compression stroke enabling easy starting. Flyweight action disengages this cam lever after a speed of 650 RPM is attained. Any engine equipped with an Automatic Compression Release camshaft does not require a spark advance mechanism. This cam has been standard on all 6, 7, 8, 10 and 12 horsepower engines since mid 1965.

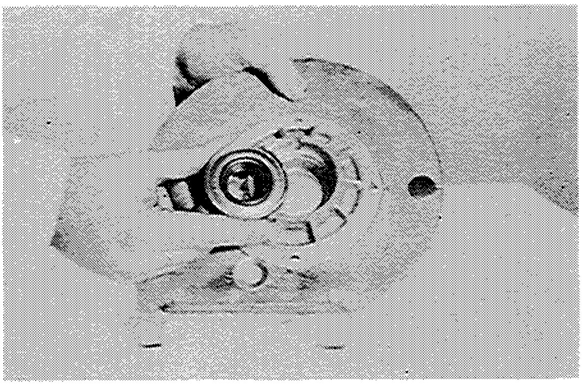


4. Install camshaft by sliding camshaft pin through block from bearing plate side and through center of camshaft. Be sure to hold breaker cam in place when installing camshafts with spark advance systems. Drive pin flush with surface of block. Shims must be used for proper end clearance.

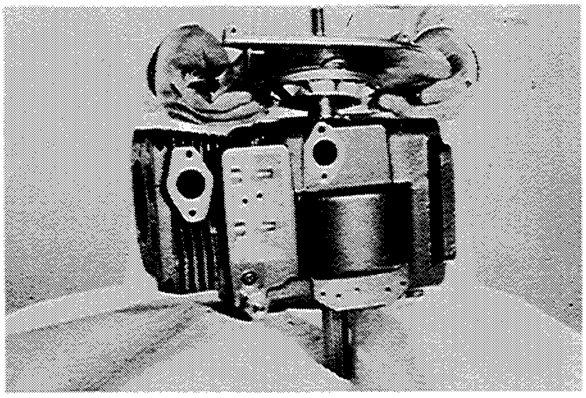


5. Install crankshaft in cylinder block. Timing marks on camshaft gear should coincide with mark on crankshaft gear. Note gear markings on camshaft and crankshaft.

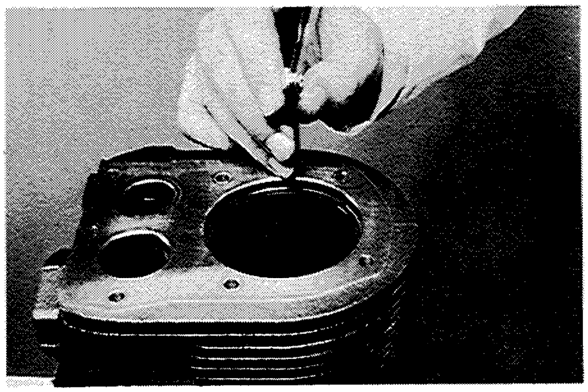




6. Press ball bearing into bearing plate. If bearing is shielded, install shielded side up.

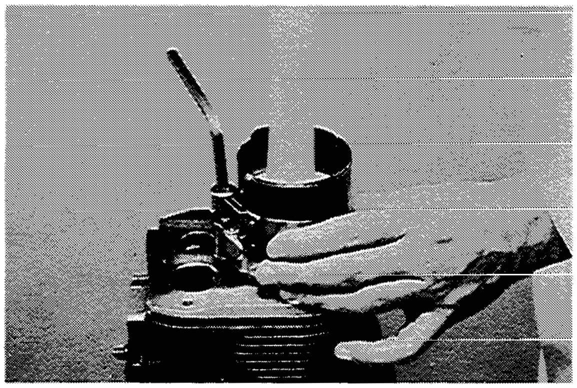


7. Install bearing plate and gasket. Use 4 cap screws with copper washers and draw up tight. Copper washers act as oil seals. Crankshaft end clearance should now be checked and compared with specifications in the manual. Install additional gaskets if necessary.

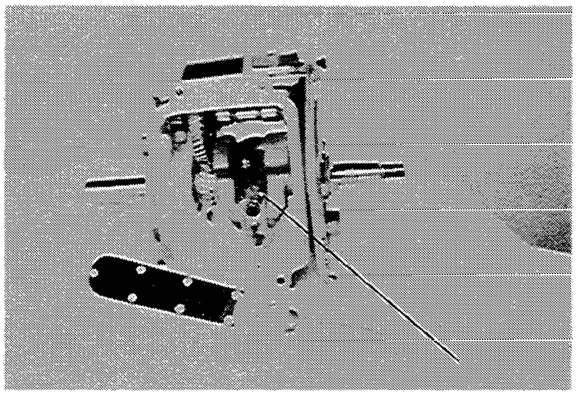


8. Check piston ring end clearance by inserting ring into cylinder bore. Be sure it is in ring travel area. Check end clearance with a feeler gauge. This gap should be from .007 to .017. Always install piston rings according to instructions given with ring sets.

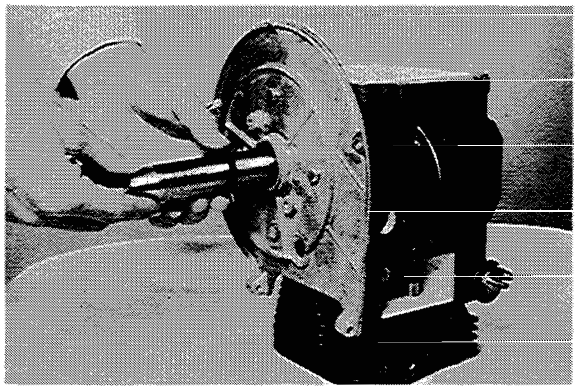
9. After oiling complete assembly, stagger ring gaps and install piston using a ring compressor. Push piston with hammer handle--DO NOT HAMMER.

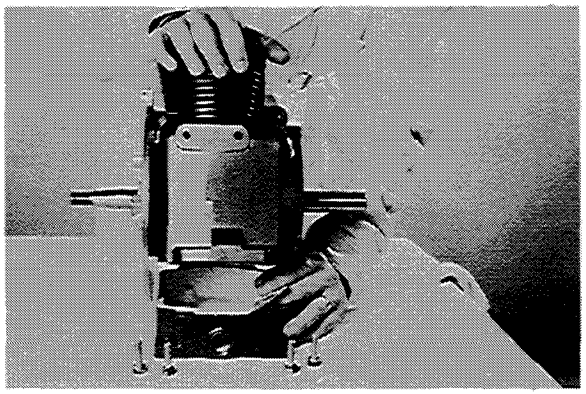


10. Connecting rod cap, lock and cap screws should be attached to connecting rod. Be sure that marks on connecting rod and cap line up and face flywheel end of engine. Note the white match marks in the illustration. Use a torque wrench to tighten cap screws according to instructions given in service manual.

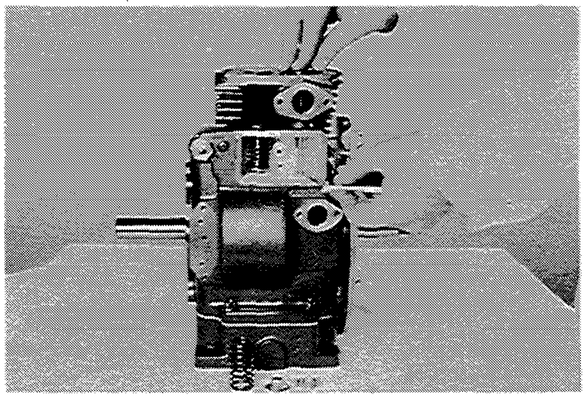


11. Install oil seals on crankshaft taking care to prevent damage to lips of seal.

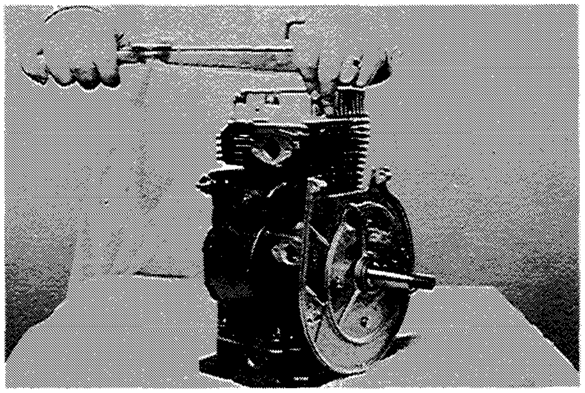




12. Assemble oil base and gasket to block with 4 screws and tighten.

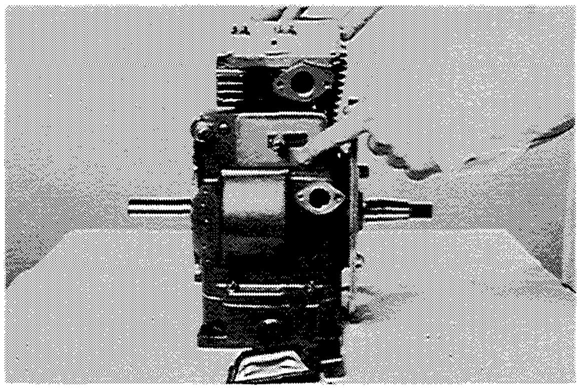


13. Install valves and check valve clearance. Be sure crankshaft is in proper position (top dead center on compression stroke). After correct clearance is obtained, install valve springs and retainers. Compress springs and place locking key in grooves of valve stems.

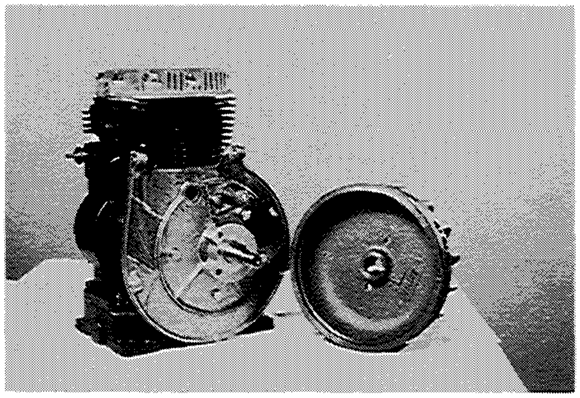


14. Install cylinder head and gasket. Always use a new gasket when head has been removed. Tighten head screws with washers evenly and in steps with a torque wrench to recommended torque as indicated in manual.

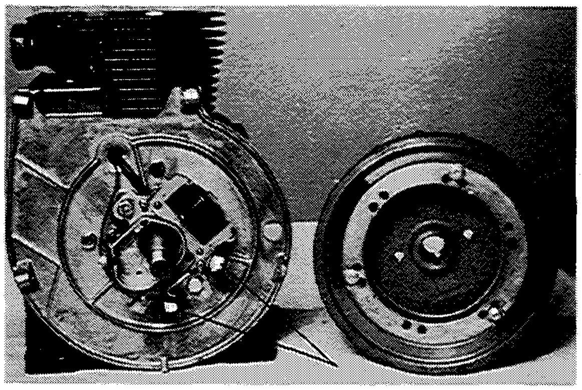
15. Install breather assembly being sure small drilled hole is in bottom of plate and reed valve faces out. This reed valve is neccessary to maintain a partial vacuum in the crankcase. If this vacuum were not present oil would leak from the crankcase.

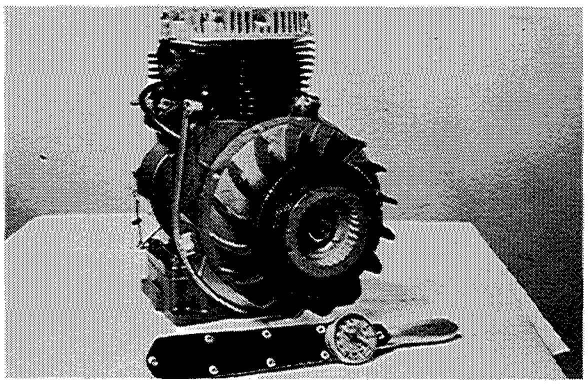


16. Install magneto on bearing plate and rotor on crankshaft.

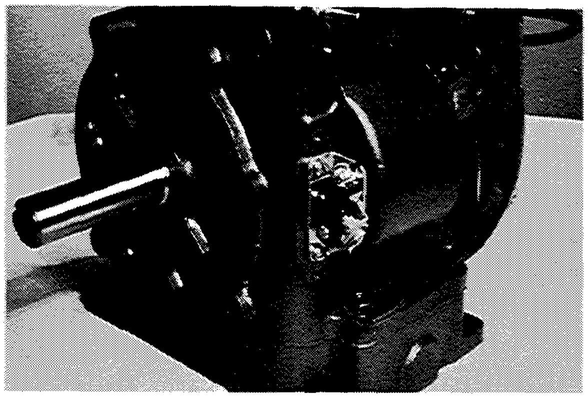


17. This illustration shows the magneto alternator. Note the two small lighting coils below and to the right of the crankshaft. The alternator produces 12 volt A. C. current for vehicle lights. This system uses a magnet ring mounted in the flywheel rather than a rotor on the crankshaft.

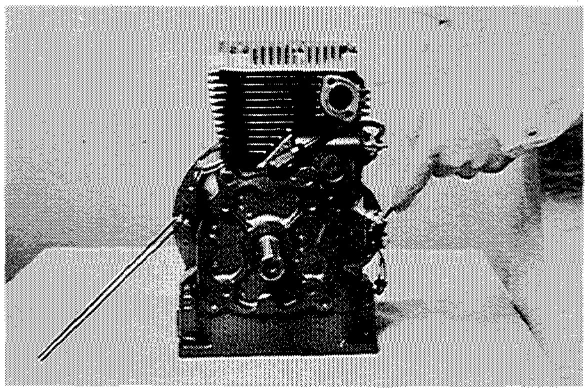




18. Install flywheel and starter pulley on crankshaft. Insert a bar between flywheel fins and torque holding nut to recommended foot pounds.

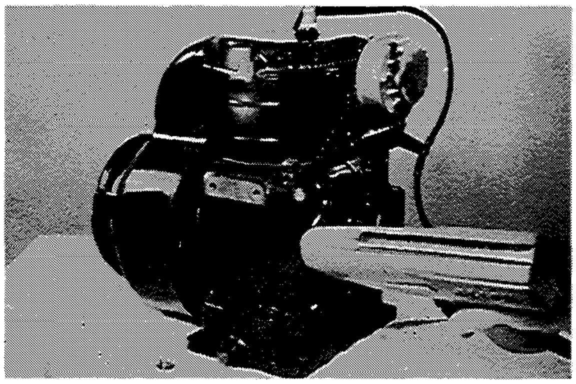


19. Install breaker push rod in hole in block and fasten breaker assembly in place with 2 screws Note that the breaker points are mounted externally on Kohler engines.

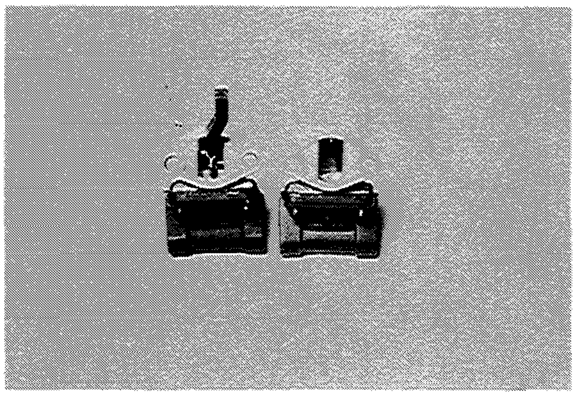


20. Set breaker point gap at .020 fully opened. For precision ignition setting use timing light at the sight hole as shown on the left side of the engine. Note timing marks.

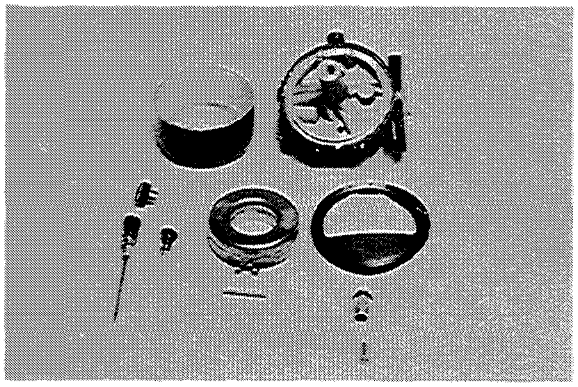
21. This illustrates use of timing light for the final ignition timing. Use the "SP" mark with engine running. Chalk the mark to make it easier to see.

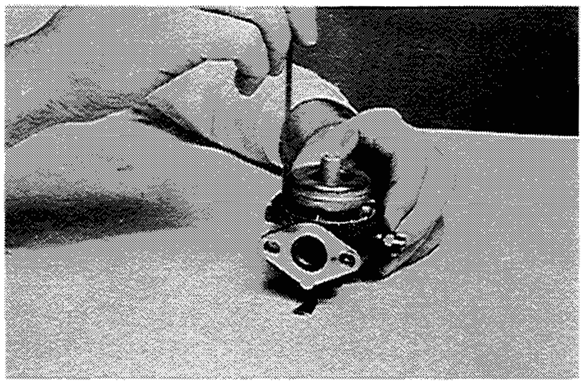


22. Install the fuel pump on the pad provided. Two types of fuel pumps are used--the pump on the left is mechanically actuated by a cam--the pump on the right is actuated by the variations in crankcase vacuum. The vacuum pump will lift fuel no higher than from the base of the engine to the carburetor and therefore is used with a gravity flow system. It is used for vehicle operation over rough terrain.

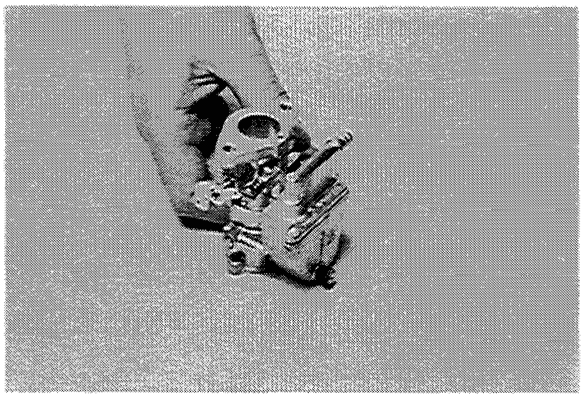


23. Assemble the carburetor components. Clockwise, starting at the top, they are - 1. Carburetor body. 2. Bowl gasket - note the splash baffle in this gasket. 3. Float valve seat. (Note: in latest carburetors valve seat is not removable.) 4. Float valve needle. 5. Float pin. 6. Float. 7. Idle jet screw. 8. Main jet screw. 9. Fuel bowl screw. 10. Fuel bowl.

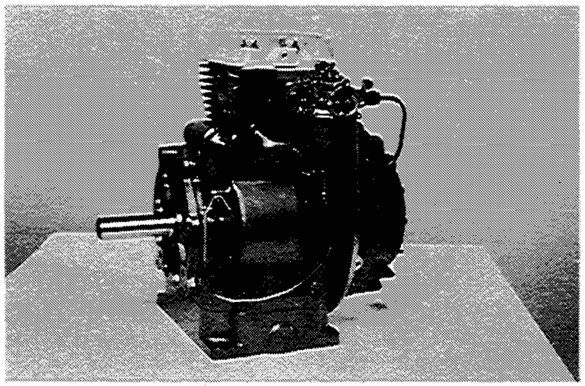




24. Set the carburetor float level as shown using the clearances given in the manual.

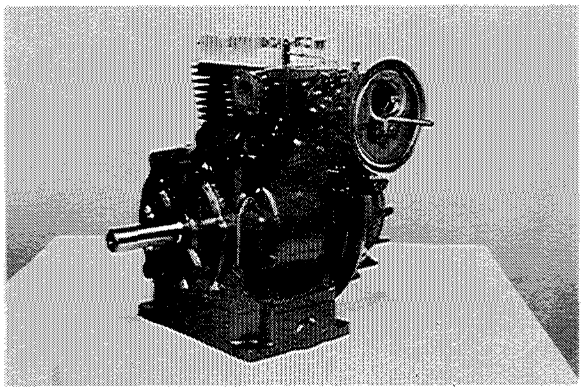


25. This illustration shows the up-draft carburetor used on the K141 engine. Main jet screw is on bottom of bowl--idle jet is on top left.

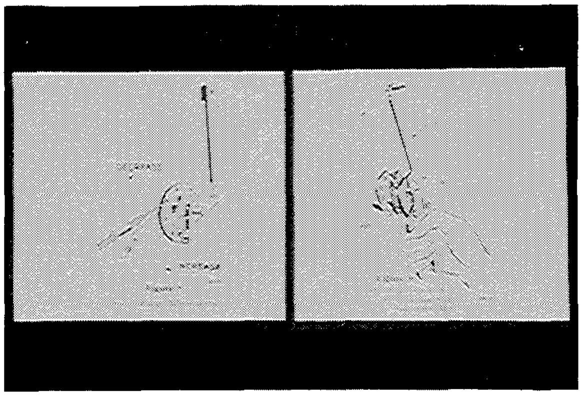


26. Install carburetor and fuel lines on cylinder block.

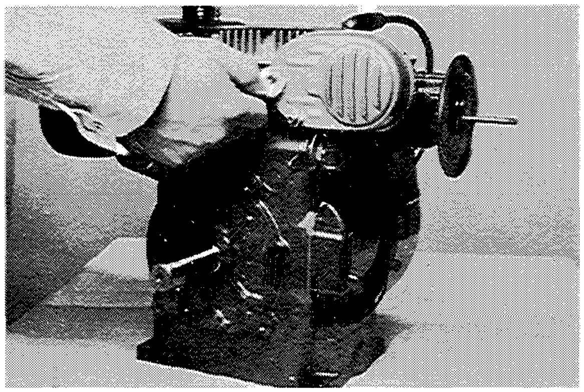
27. Install governor arm and linkage. This view shows the governor as used on the K91 through the K181. For this governor settings see the service manual. Add air-cleaner base.

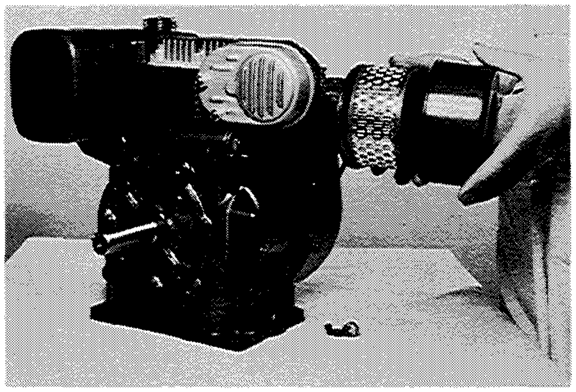


28. To adjust governor before tightening clamp bolt, turn shaft counterclockwise as far as possible using a pair of pliers. Pull arm as far as possible to left (away from carburetor). Note: The length of travel of the governor arm must equal the length of travel of the throttle arm or the governor will not work. Tighten nut and check for freedom of movement. To increase or decrease top speed, change position of throttle bracket as shown. Caution: Do not over-tighten bushing nut. Again, see the service manual for other models.

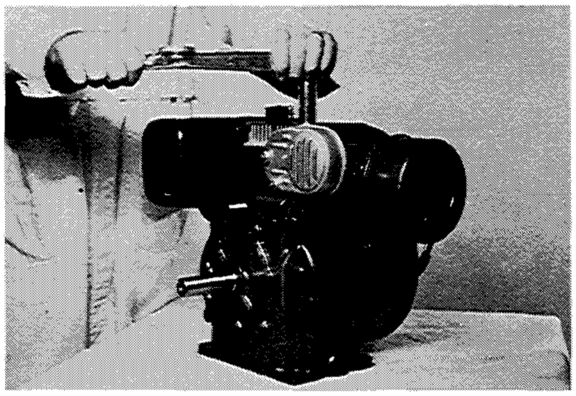


29. Install sheet metal shrouding, fuel tank, and muffler.

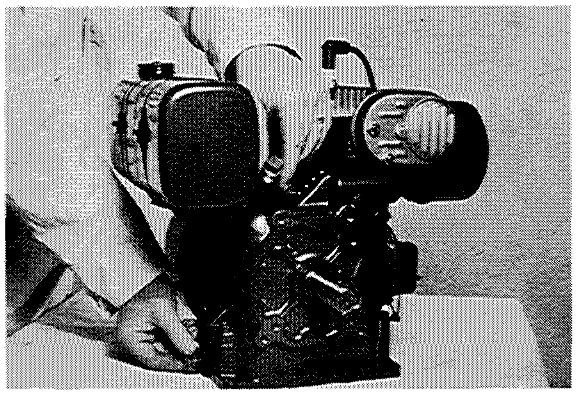




30. Install air-cleaner carefully. The dry type air-cleaner is standard equipment on all Kohler single cylinder engines. Be sure washer is installed under wing nut. When replacing elements, be sure back plate and cover offer flat surfaces so that no air can enter except through the filter element.

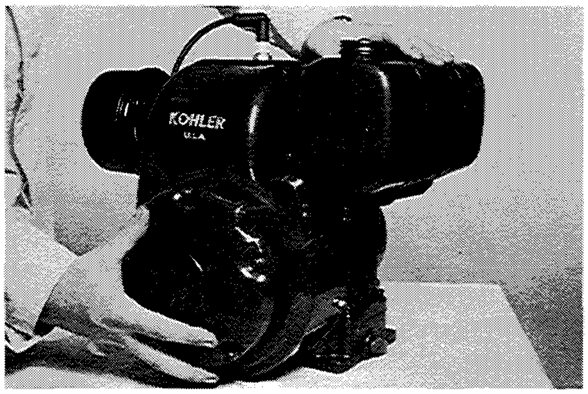


31. Install spark plug and torque to 27 ft. lbs.

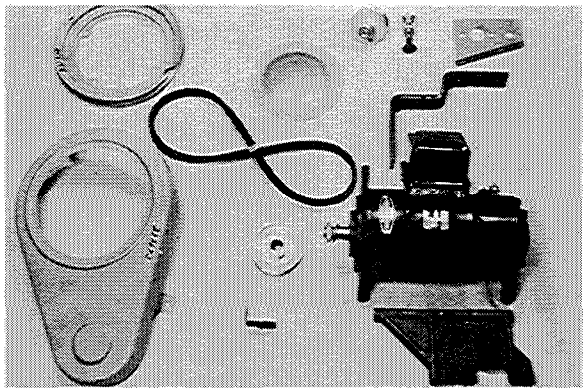


32. Install dipstick and drain plug.

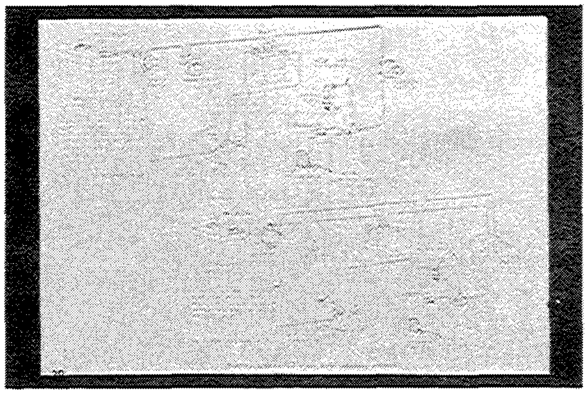
33. Position retractable starter on blower housing and tighten screws.

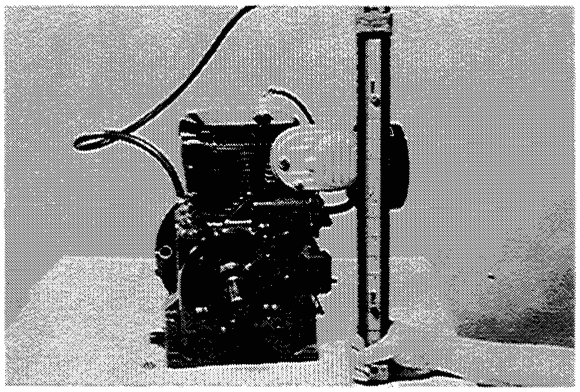


34. Some applications use electric starting. The standard electric starting components are shown in this view. Clockwise from upper left corner-
1. Flywheel pulley. 2. V-belt. 3. Air intake screen. 4. Starter switch. 5. Ignition switch.
6. Switch panel. 7. Upper starter bracket.
8. Starter-generator with voltage regulator.
9. Lower starter bracket. 10. Spacer bracket.
11. Starter-generator drive pulley. 12. Belt guard.



35. Two basic types of electric start systems are used. The top view uses a start switch while the bottom uses a starter solenoid.





36. The crankshaft breather maintains a partial vacuum in the crankcase. This vacuum should be checked occasionally with a water manometer or vacuum gauge inserted at the oil filler hole. A vacuum of 5" to 10" water column or 1/2 to 1" mercury should be present when engine is running. Lack of vacuum indicates a faulty breather, excessive engine blowby, leaky valves, or worn oil seals.

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CONTENTS

CHAPTER ONE

Introduction

Down through the ages, man has progressed. His living standards improved as he learned to harness various forms of energy to do work for him.

His first accomplishment was to domesticate and train animals to carry materials and eventually to pull simple machines. Later man learned to get useful work from flowing water by means of water wheels. Today a portion of the electricity we use in homes and factories is developed from turbines and generators--an application of the age old water wheel principle.

Next came the use of the so-called fossil fuels, coal and oil. Changing the latent energy of coal and oil into useful mechanical work is accomplished in a variety of ways and we will discuss this in more detail later..

The sun is the original source of the energy in the fossil fuels. Coal and oil come from former living organisms and without the sun and its energy that life would not have been possible. The sun is still pouring down a tremendous amount of energy and only a very small fraction of it has ever been put to work. Scientists are studying ways of harnessing the energy from the sun, but so far, no big strides have been made.

Atomic energy is the newest basic source of energy to be exploited. This holds tremendous promise for the future and we can expect an improvement in our average standard of living as the result of peaceful use of atomic energy.

Of all the sources of energy indicated above, we obtain by far the greatest amount of work from coal and oil. The process of releasing energy from coal has reached its highest development in coal powered steam generating plants for providing electricity which has become an everyday necessity for all of us.

Steam engines operated from coal-fired boilers have also been used in providing useful work. However, they have many limitations and their use is decreasing. The reciprocating steam engine and steam turbines are classed as heat engines of the external combustion type. In other words, combustion of the fuel and release of the heat energy is accomplished at some external point of the engine.

In contrast to this, the release of energy from oil has reached a high state of development in the internal combustion engine. For example, the gas turbine type of engine such as used in jet aircraft is one form of internal combustion engine. But we will limit our discussion to the reciprocating or piston type internal combustion engine.

Historical Highlights

To get a good over-all understanding of any subject, it helps to have some knowledge of its past history and development. Briefly, here are some of the highlights of internal combustion engine history.

In 1824, Carnot, a Frenchman, described a theoretical heat engine process. This was an ideal process and is still recognized as the aim in the development of any engine. However, engineers to this date have been unable to develop the maximum conversion of heat energy into work as was described in Carnot's theory.

In 1838, Barnett, an Englishman, described a two stroke cycle engine. His description was also theoretical and although attempts were made to develop a working model, many difficulties were encountered.

During the Civil War period, Beau de Rochas, a Frenchman, set forth the principles of the four stroke cycle. However, it was not until 1876 that a German by the name of Otto built the first successful four stroke cycle engine. The gasoline engine down to this day is often called an Otto cycle engine.

In 1892, another German, Rudolph Diesel, proposed an engine in which the air and fuel mixture would be ignited by the heat developed during rapid compression.

The development of engines in the 19th century was influenced by the need for pumping water from the early coal mines. Man's usage of coal was accelerating and it became necessary to go deeper into the ground for more coal. Hand powered pumps became impractical as the volume of water to be handled increased. The first engines developed for the mines were huge machines of small power output.

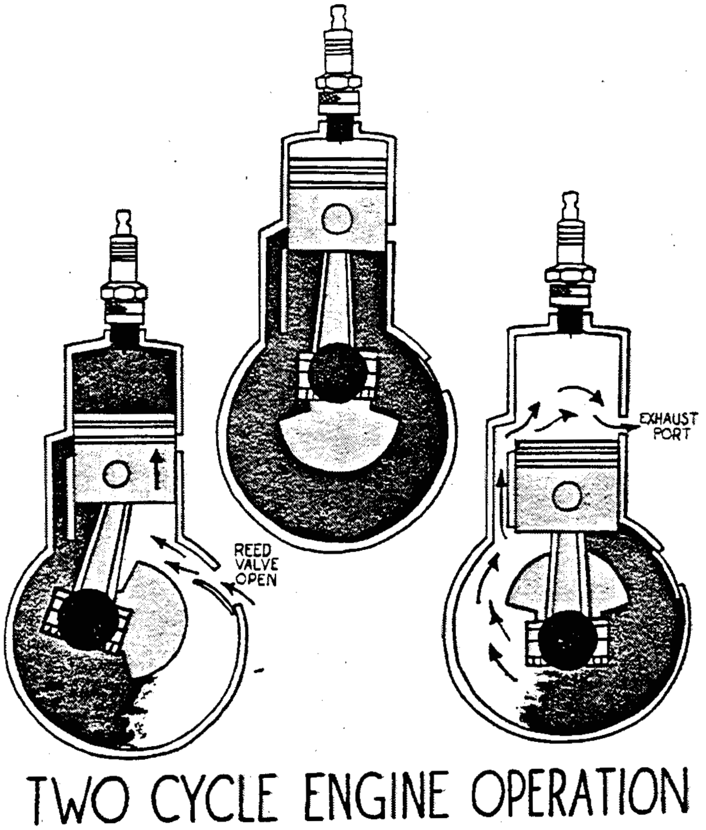


Figure 1.1

Two Stroke Cycle.

Engines are described by the number of strokes required by the piston to complete one operating cycle. A stroke is defined as movement of the piston from one end of its travel to the other. It may be either toward the crankshaft or away from it.

In the two stroke cycle engine or two cycle engine, as shortened in every day usage, one operating cycle is completed for every two strokes of the piston or one revolution of the crankshaft. Air is usually introduced through holes or ports in the cylinder wall.

As the piston moves up, these ports are closed and the charge is compressed. The fuel and air mixture is ignited when the piston is near the top dead center and the rapid burning and expansion of the gases forces the piston downward again. Part way down in its travel, other ports are opened allowing the burned gases to exhaust and clean the cylinder in preparation for the next incoming charge. Two cycle operation is used today in both gasoline and Diesel engines.

Four Stroke Cycle

All engines used by Kohler Co., gasoline or Diesel, operate on a four strokecycle principle. A firm understanding of what happens in the cylinder during these four strokes is important. This sequence should be memorized. The four strokes are as follows:

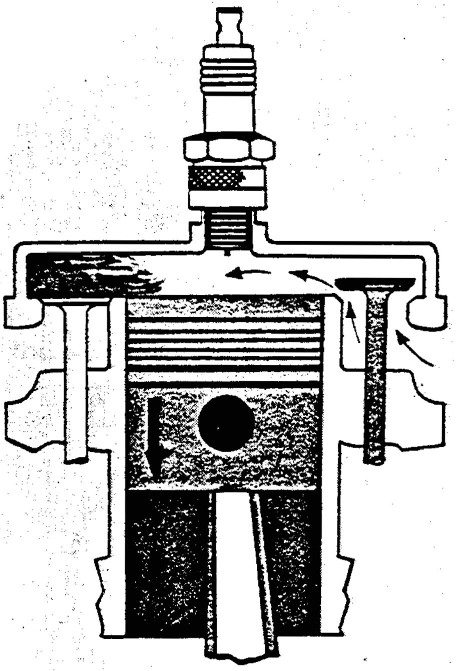


Figure 1.2

a. Intake Stroke -- At the beginning of this stroke, the piston is at the position closest to the cylinder head, thereby filling the cylinder space and reducing the open volume of the cylinder and combustion chamber to a minimum. As the piston moves toward the crankshaft and with the intake valve open, air is drawn into the cylinder.

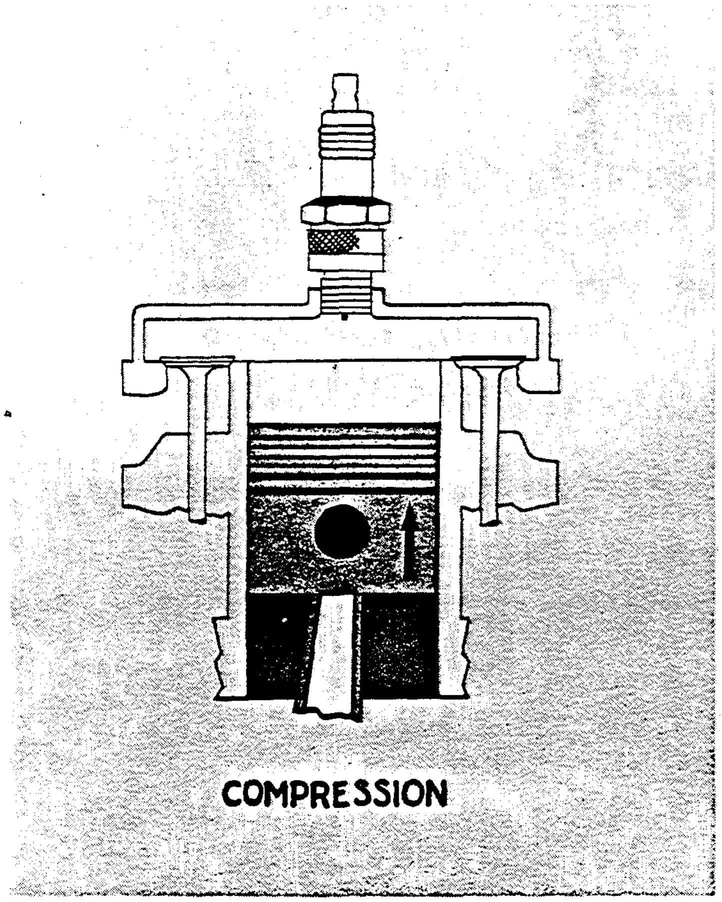


Figure 1.3

b. Compression Stroke -- With air in the cylinder and the piston at the bottom or at the point closest to the crankshaft, the intake valve closes. Since there is no other opening, the air in the cylinder is compressed as the piston travels toward the top of the cylinder. In the case of the gasoline engine, the fuel is already mixed with the air as it is drawn into the cylinder. In the Diesel engine, fuel is injected into the cylinder toward the end of the compression stroke. Just before it reaches top dead center, or the point where it is farthest from the crankshaft, the charge is ignited. This is true of both gasoline and Diesel engines.

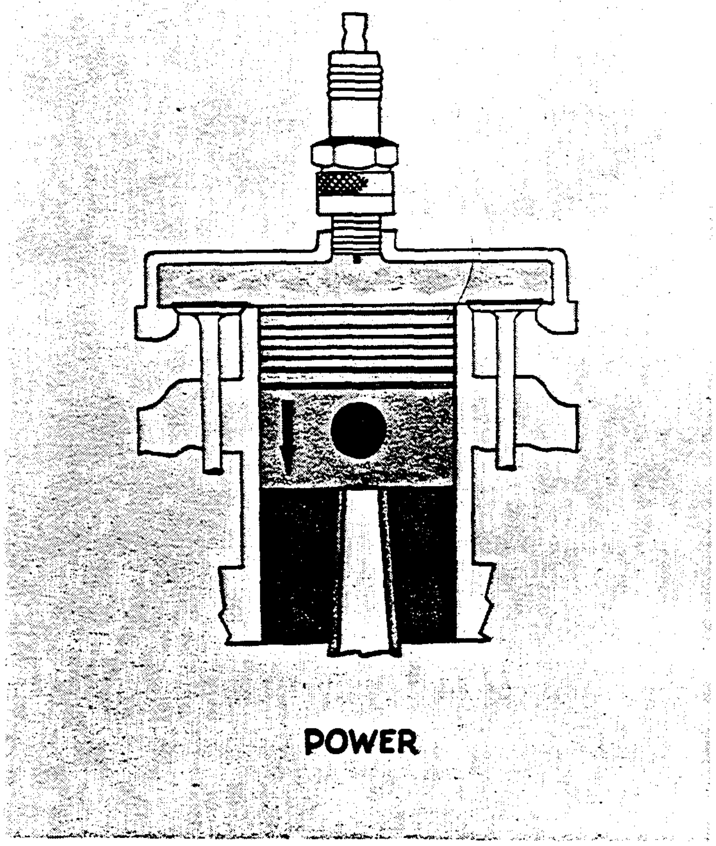


Figure 1.4

c. Power Stroke -- As the fuel burns in the cylinder, heat is released causing a rapid pressure buildup as the gases expand. This pressure on the piston causes it to move downward, through the mechanism of the connecting rod and crankshaft delivering useful energy to the rotating crankshaft.

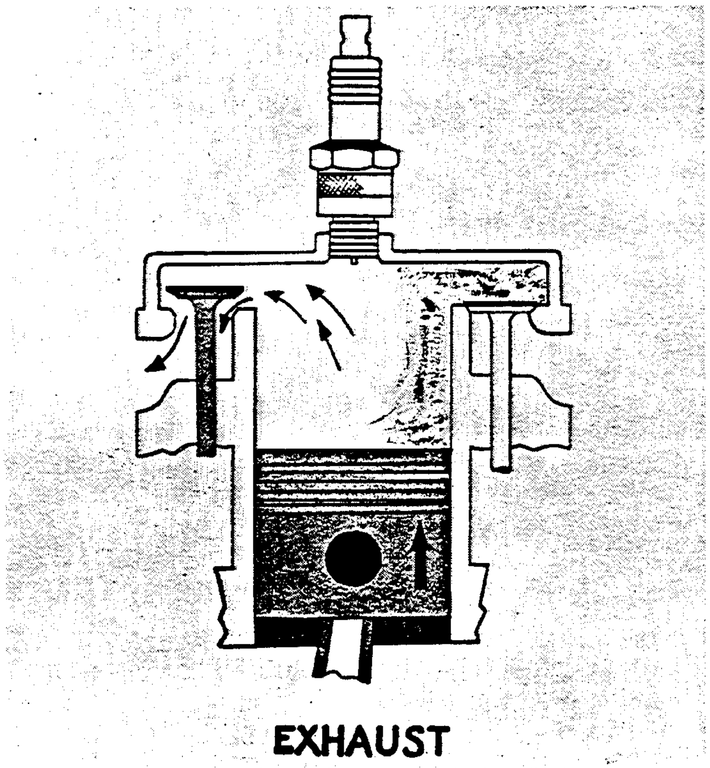


Figure 1.5

d. Exhaust Stroke -- At the end of the previous power stroke, the exhaust valve opens, and as the piston moves upward the exhaust is forced out of the cylinder. The exhaust valve closes at the end of this stroke and the engine is ready to repeat the cycle.

FOUR CYCLE ENGINE OPERATION

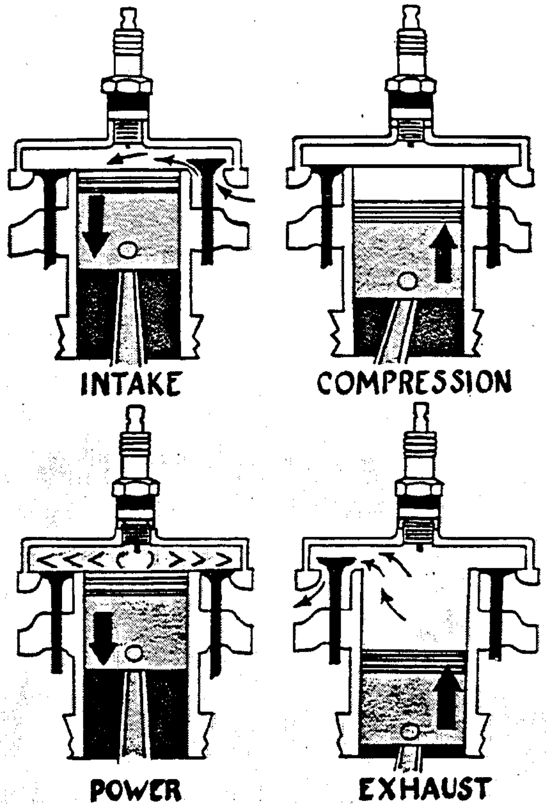


Figure 1.6

Engine Compression Factors.

Displacement of an engine in cubic inches is a measure of the size, or potential power of the engine. By definition, it is the volume which the piston displaces. In other words, the displacement for a single cylinder engine can be calculated as follows. Piston area multiplied by the length of stroke or $\frac{\pi}{4}$ X (Cylinder bore)^2 X Stroke. For a multi-cylinder engine, this quantity is determined for one cylinder and simply multiplied by the number of cylinders in the engine.

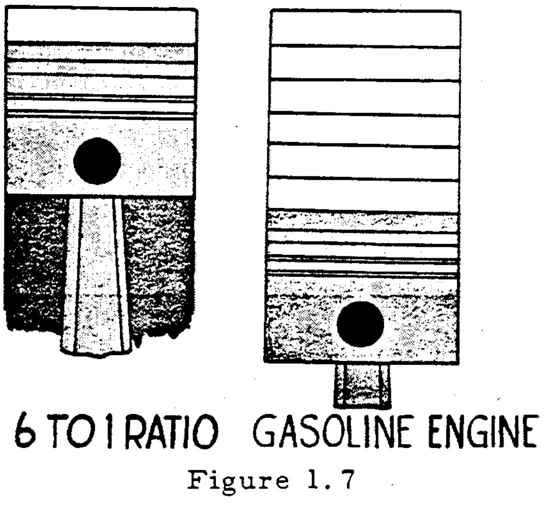


Figure 1.7

Another engine feature is compression ratio. In every engine there is a small volume of air around the heads of the valves and in the contours of the combustion chamber, even when the piston is at top dead center. This is called the clearance volume. This volume plus the piston displacement is the total volume. Compression ratio is defined as the total volume divided by the clearance volume -- or displacement plus clearance volume divided by clearance volume. As a formula it may be expressed:

$$\text{C.R.} = \frac{V_{\text{Total}}}{V_{\text{Clearance}}} = \frac{V_{\text{Displ.}} + V_{\text{Clear.}}}{V_{\text{Clearance}}}$$

The amount of power an engine develops is directly related to the degree of compression achieved in the cylinder. The efficiency with which the fuel is burned is also higher with a high degree of compression. This is the reason for the trend in automotive engines toward higher compression ratios.

Progress toward higher compression ratios is limited by the burning characteristics of the fuel. In overhead valve engines, where the valves are normally directly over the engine, there are no limitations in design for achieving a high compression ratio because it is easy to design such an engine with a small clearance volume. With "L" head engines, such as our air cooled models, it is not easy to keep the clearance volume small and therefore we are limited to compression ratios in the range of 6 to 6.5.

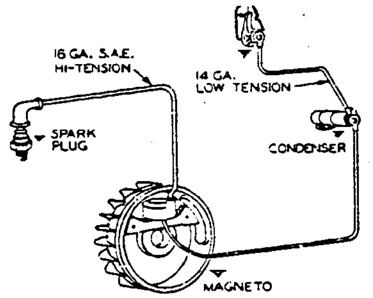
The engine features which hold the compression and power stroke pressures in the cylinder are the valves and seats, the cylinder head gasket and the piston rings. To get proper power from a given engine and to get proper starting characteristics, there can be no leakage through any of these parts.

In Diesel engines the pressures in the cylinder during compression and combustion range from 700 to 1200 psi. as compared with 300 to 500 psi. in gasoline engines. Compression ratios in Diesel engines range from 15:1 to 20:1 as compared with 5.5:1 to 10.5:1 for gasoline engines.

As air is compressed in the Diesel engine cylinder, its temperature increases. If this is done very rapidly, there is insufficient time for this heat to escape to the surrounding cylinder walls. With a high compression ratio and rapid compression of the air, temperatures can be reached which will ignite the fuel when it is injected into the cylinder. This is known as compression ignition and is the characteristic operating principle of Diesel engines.

Spark Ignition.

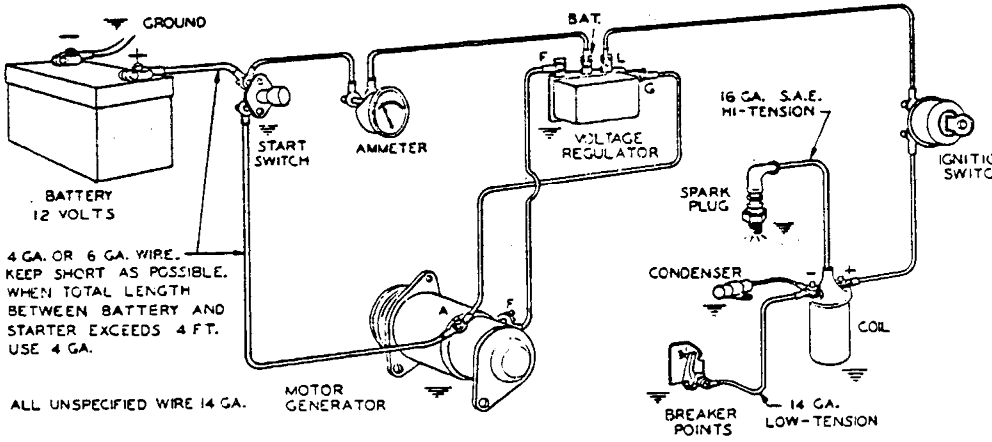
In gasoline engines the fuel and air mixture is ignited by means of an electric spark. The spark jumps from one spark plug electrode to the other in the combustion chamber. The electricity for that spark must be of high voltage in order to jump the gap, but can be of relatively small current flow.



Magneto Ignition
Figure 1.8

The high voltage is produced in a coil. The coil has two windings. Current is flowed at low voltage through the primary winding of the coil which is relatively heavy wire and few turns. The charge of current in this winding causes a high voltage, low amperage current in the secondary winding. This is true of both magneto and battery ignition systems. The current for the primary winding of a battery ignition system comes from the battery.

In a magneto system this primary current is generated by a rotating permanent magnet which induces current in a near-by iron core and from there into the primary winding of the coil. Interruption of the primary current by means of breaker points on both battery and magneto systems causes a rapid change in the coil and thereby produces the high voltage necessary at the spark plug. This voltage may run as high as 20,000 volts with approximately 7,000 being required for initial starting.



Battery Ignition
Figure 1.9

Timing of the spark is essential to obtain maximum power from the engine. The point at which the spark should occur will vary with the speed and the design of the engine. Under running conditions, the spark should occur before the piston reaches top dead center so that the burning of the fuel has started before the piston begins its downward stroke. Maximum pressure is necessary to get the maximum work from the rapidly expanding gases.

Combustion of The Fuel & Air Mixture.

Many people think of engine combustion as an explosion or simultaneous burning of all parts of the fuel and air mixture. This is incorrect.

The type of combustion desired in an engine is a progressive burning of the fuel and air mixture. The flame starts at the spark plug and travels in all directions from that point. It can be influenced by extreme turbulence of the fuel and air mixture. Researchers have actually photographed this flame front at various stages as it proceeds across the combustion chamber.

As the flame travels, heat is generated and gaseous products of combustion are released. A rapid buildup of pressure results. This pressure is also built up on the forward side of the flame in the fuel and air mixture which the flame has not yet reached. The pressure and temperature of this forward part of the mixture may reach the point where it is ignited by itself, similar to Diesel ignition.

A very rapid buildup of temperature and pressure is produced and combustion becomes uncontrolled. Ignition of the charge in front of the flame front is known as auto-ignition or detonation. Another form of uncontrolled combustion is caused by some spot in the cylinder remaining hot enough after the exhaust stroke to ignite the incoming mixture before the normal spark ignition. This causes an abnormal buildup of pressure, rough sounding operation and loss of power. It is known as pre-ignition. All such forms of uncontrolled combustion result in excessive pressures on rings, pistons, cylinder heads and bearings and loss of power output. Extended operation under such conditions will lead to mechanical failure of some part of the engine.

The air and fuel mixture in a gasoline engine must be within certain limits in order to ignite and burn. The extreme limits of the ratio of air to fuel weights are approximately 7:1 for a rich mixture and 20:1 for a lean mixture. For our engines this range is apt to be much narrower and operation will usually fall in the range from 10.5:1 to 14:1. Maximum power is usually obtained around 13:1 air fuel ratio.

In a Diesel engine, combustion starts shortly after the beginning of fuel injection. The fuel is sprayed into the combustion chamber at a carefully calibrated rate. The amount of power the engine will develop is determined by the length of time the fuel is injected. The pumps are so constructed that this time is varied according to the setting of the governor. Where the governor on a gasoline engine varies the position of the carburetor throttle, the governor on a Diesel engine varies the length of time that fuel is sprayed into the cylinder.

Valve Timing & Lift.

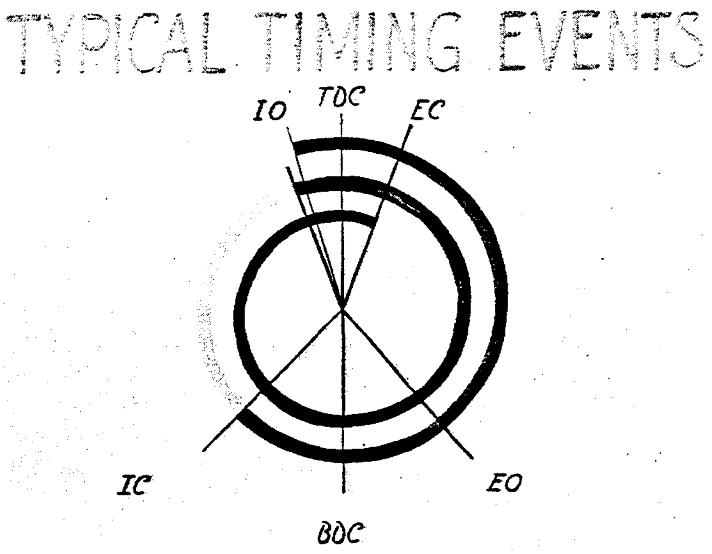
Referring again to the four basic strokes in a four stroke cycle engine, we must provide for the opening of the intake valve before we start the intake stroke. During the first part of the valve opening, movement is small in comparison with crank angle travel. In order to have the valve open a suitable amount by the time the piston starts drawing air into the cylinder, we must start the opening of the intake valve before the piston reaches top dead center. Then we must open it as fast as mechanically possible and far enough to provide the minimum resistance to flow of air through the valve port.

When the piston approaches bottom dead center, air is being drawn in at a rapid rate. Because the air has inertia we can keep the intake valve open somewhat beyond bottom dead center and the momentum of the air in the intake system tends to pack more air into the cylinder. The ideal place to close the intake valve would be at the point where air movement through the intake valve starts to reverse itself. In most high speed engines in use today, this point will range from 35° to 65° of crank travel beyond bottom dead center.

Intake valve closing, therefore, is always after bottom dead center and is specified in those terms. Both valves are closed during the compression stroke and the early part of the power stroke. During the power stroke, some of the energy from the expanding gases is sacrificed to make sure that the exhaust gases are completely cleared from the cylinder in preparation for the next intake stroke. It is common practice to open the exhaust valve before bottom center for intake valve opening.

Cams are designed to provide: (1) a clearance of a few thousandths of an inch during a part of the cycle when the valves must be closed, (2) a ramp for engaging the valve and starting its lift, (3) a portion to accelerate the valve to maximum opening velocity, (4) a section to decelerate it to a stop at the cam nose, and (5) the other half of the cam lobe which closes the valve again through the same sequence but in reverse.

The intake manifold, valve ports and throat area of the combustion chamber must be of such size and shape that air may flow through with minimum restriction. Accumulations of carbon or lead deposits in any of these areas will immediately decrease the maximum power.



intake opening — 15° before top center
intake closing — 50° after bottom center
exhaust opening — 50° before bottom center
exhaust closing — 15° after top center

Figure 1.10

The intake valve ordinarily does not achieve excessively high temperatures. It is cooled by the incoming air and fuel mixture. The exhaust valve, however, receives the full blast of the exhaust gases and can dissipate only through the valve guide and valve seat. Ordinarily at wide open throttle the exhaust valve will be red hot. You can see it through the exhaust port. To withstand such temperatures, the valve head must be of stainless steel or it will corrode very rapidly. For extreme conditions, the face of the valve must also be coated with stellite to provide sufficient hardness and corrosion resistance. Valve rotators aid in providing good valve life under heavy load conditions.

Flywheel.

An engine produces its power during the power stroke only. Therefore, there must be sufficient momentum built into the engine to carry it through the other three strokes without injurious loss of speed. This function is performed by the flywheel.

Ordinarily our flywheels are designed somewhat on the light side to reduce engine weight. We depend on the equipment being driven by the engine for part of the flywheel action. Even at best, there is always some slowing down of the engine between power strokes. This slowing down and subsequent speeding up during the power stroke is termed cyclic irregularity. This becomes important on certain applications where difficulty with couplings, drive pulleys or clutches is experienced. Such components must be adequate to take this speed variation.

Engine Vibration & Balance.

In a single cylinder engine the reciprocating action of the piston and connecting rod causes a shaking action which must be balanced as far as possible. By putting a counter-weight on the crankshaft opposite the crank throw, the reciprocating unbalance can be counteracted. If we provide for 100% counteraction in the direction of the unbalance force, then the counterweight sets up an equal unbalance in a plane perpendicular to the axis of the cylinder. Therefore, as a compromise, we counterbalance single cylinder engines by counterweighting 50% to 75% of the weight of the piston and rod. The balance of multi-cylinder engines is more complex, but the same basic principles apply.

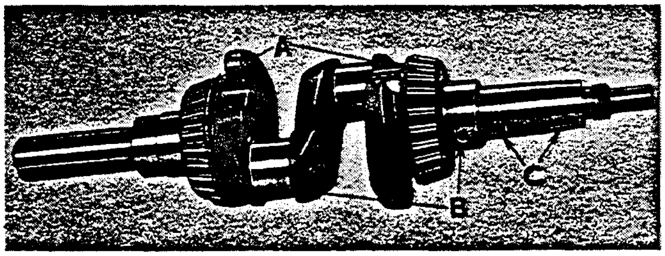


Figure 1.11

Cooling.

As mentioned previously, cooling of valves is a critical part of engine performance. The exhaust valve transfers its heat through the stem and into the guide which in turn conducts it to the outside of the cylinder block. Some valve heat is also transferred through the seating face to the valve seat insert and from there to the surrounding portion of the block.

Providing adequate cooling air or cooling water, depending on the type of engine, to that portion of a cylinder block is of prime importance. The cylinder head contains most of the combustion chamber and becomes hot during the power stroke. It must be cooled so that the head itself retains its physical strength and shape and to prevent the hot spots from developing in the combustion chamber, causing pre-ignition. The piston is cooled, to some extent, by oil splashing against the underside of it. The piston rings transmit heat from the piston to the cylinder walls. The heat picked up by the cylinder walls, plus that resulting from direct exposure to the combustion flame, must be disposed of by air forced through cooling fins around the cylinder of an air-cooled engine or by a water jacket on the water cooled engines.

If the cylinder is inadequately cooled, the oil temperature tends to run high and will break down in the ring section causing ring sticking and excessive carbon and varnish buildup. Providing a blower for cooling air requirements of an engine, whether it be air cooled or radiator cooled, ordinarily takes from 5% to 10% of the available engine power.

Lubrication.

A very thin film of oil is adequate to lubricate cylinder walls. The rings are designed to scrape excess oil from the walls and prevent passage of excessive amounts to the combustion chamber. Gasoline and Diesel engines are lubricated to some extent on the upper portion of the cylinder by the fuel itself. When operating on gaseous fuels, such as propane and natural gas, some engines run so dry that a top oiler must be added for providing sufficient lubrication for the upper end of the piston travel.

The connecting rod bearings are critical parts of the engine. High and varying pressures and high rotating speeds make the lubrication job at this point important.

In splash lubricated engines, such as our smaller one cylinder engines, the oil must find its way into the bearing surface through drilled holes or grooves after being picked up as droplets during the rotation of the crank and connecting rod. The simplicity of a splash lubrication system is desirable on smaller engines in order to keep costs to a minimum.

On our larger engines, such as the K331 and K662, we use a gear type oil pump to force oil through the drilled passages to various spots in the cylinder block where bearings, including the connecting rod bearing, are present. We provide an oil transfer sleeve between the cylinder block and the crankshaft in order to get oil into the shaft. From there it goes through drilled passages to the crank pin journals where they feed the connecting rod bearings. Pressure lubrication to the connecting rod bearings is advantageous in providing a more positive supply and definite oil circulation through the bearings. A certain amount of cooling of the bearings is accomplished with the oil.

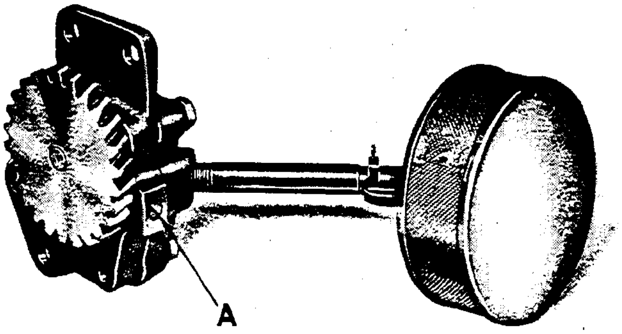


Figure 1.12

The lubrication of sleeve type main bearings such as used on the L600 and the larger purchased engines is provided by oil pumps and drilled passages, the same as for the rod bearings. An anti-friction bearing, such as the ball and roller bearings used in our smaller engines, needs very little lubrication. In fact, it is undesirable to allow excessive amounts of oil to pass through the bearings.

Camshafts, timing gears, governor, magneto and oil pump drive gears are very lightly loaded and receive adequate lubrication just from oil thrown off from other parts in their vicinity. The camshaft bushings on larger engines receive pressure lubrication, but it is not at all critical. Lubrication around the flyweights of a governor must be moderate and excessive amounts of oil will adversely affect the action of the flyweights. Reduction gears are highly stressed and must be lubricated very carefully.

OIL CHART
API Service MS

Air Temperature	Single Viscosity Oil	Multiple Viscosity Oil
Above 30° F.	SAE 30	
30° - 0° F.	SAE 10	SAE 10W-30
Below 0° F.		SAE 5W-20

The question frequently comes up whether we should use a straight mineral oil or one which includes detergents. Normally we recommend the heavy duty grade which always includes detergents. During initial run-in periods (in field service) on engines equipped with an oil pump there may be some advantage in using a straight run mineral oil. Any particles which are worn off surfaces during the run-in period would then have a tendency to accumulate in the oil sump rather than being continually pumped through the engine bearings. In a splash lubricated engine where the oil in the sump is continually churned up, there is no advantage in using a straight mineral type oil for run-in. The run-in on our test line is a different matter. The oil used maintains a fairly thin film allowing surfaces to rub off any high spots, yet preventing seizure or scoring. This type oil should not be used on heavy load for a very long period and is not recommended for field use.

Detergent type oils have the advantage of keeping valve stems, rings and cylinder walls relatively free of accumulations of carbon or varnish. It also prevents sludge accumulations in the crankcase and keeps that sort of material in suspension in the oil. Frequent draining and replacement of the oil is still necessary as with other oils, to prevent detergents from becoming overloaded with sludge materials. If detergent oil does become completely loaded it may suddenly become a jelly-like mass making further operation of the engine impossible. The operator seldom realizes that the oil is in this condition and it frequently results in burned out bearings.

There is no substitute for periodic draining and replacement of the oil supply.

There are a number of special additives on the market. Although some of these materials have merit for certain conditions on some engines, we believe that with adequate maintenance and proper engine use, special additives are unnecessary.

Fuels.

Gasoline. Petroleum is a mixture of a large number of different hydrocarbons -- materials composed of hydrogen and carbon. These two elements may be combined in a wide variety of ways with each combination being quite stable and having its own individual boiling point and ignition point. If you were to heat a quantity of gasoline, you would find that a certain portion of it would boil off at approximately 100° F and other portions would boil off at intermediate points between that temperature and 250° to 300° F. This characteristic varies quite widely, depending on how the gasoline was refined. The characteristic of a varying boiling and ignition point is the principle reason for gasoline being a superior engine fuel. Alcohol, on the other hand, is a single chemical compound with a single boiling and ignition point for a given pressure. When alcohol is used as a fuel it has a tendency to burn too rapidly and uncontrollably. The basic chemistry of gasoline allows it to burn in a controlled sequence according to the temperature and pressure required for the various hydrocarbon materials.

Octane is one of the hydrocarbon compounds in gasoline. It has superior anti-knock characteristics and at one time was considered the ideal or nearly perfect engine fuel. It was therefore used as a basis for comparing the anti-knock performance of various gasolines. The octane rating has developed from this concept and two different methods of rating gasolines are in current usage; the research method and motor method. The research method is the original one and is always the higher of the two ratings.

Tetraethyl lead also has excellent anti-knock characteristics. In developing engines of increasing efficiency and more power from a smaller size, it has been necessary to design engines of ever increasing compression ratios. It was impossible or uneconomical to refine gasolines which would perform without knock in these high compression engines unless tetraethyl lead was added to the gasoline. Certain other compounds are formed by the action of the lead and the fuel during engine combustion. Some of these compounds deposit on the walls of the combustion chamber, the top of the piston and the valves. Most of the deposit buildup observed in such areas is the direct result of the lead in the fuel.

The question is frequently asked whether we can use white gas in Kohler engines. It may be possible under light load conditions, but normally speaking we must discourage its use because knocking occurs under load. Most white gas has a low octane rating. A rating of at least 75 is recommended for Kohler engines. Most regular grades of gasoline today are 90 octane or better.

When gasoline is stored for any extended period of time, certain portions of it tend to oxidize and thereby form a heavy gummy substance. This gum can plug up the tiny holes in carburetors and thereby cause unsatisfactory engine performance. The best way to avoid this condition is to avoid lengthy storage of the gasoline.

Gaseous fuel. Engines can be made to run on gaseous fuels such as propane, butane, natural or manufactured gas. The energy potential of these fuels is as follows:

Propane-Butane -- 2600 - 3300 BTU/cu. ft.
Natural Gas -- 1000 BTU/cu. ft.
Manufactured Gas -- 400 - 600 BTU/cu. ft.

Natural gas, being roughly 1/3 the BTU value of propane, must be supplied in three times the volume required for propane for a given engine power output. Manufactured gas is always quite low on BTU value and is sometimes modified or enriched with natural gas. It is important to know which gas is to be used when furnishing carburetion equipment for a specific job. The low value gases require regulators, lines, etc. which will supply many times the volume of propane gas for a given power output required.

One big advantage of gaseous fuels is their freedom from tetraethyl lead. Deposits in the combustion chamber are kept to a minimum.

Diesel fuel. The Diesel fuel is simply specified as grade #1 and #2. Grade #1 is generally a lighter weight or lower viscosity.

Cetane rating is the quality of the fuel which compares with octane rating in gasoline. The minimum cetane rating is usually considered 45. In low temperatures, it is quite common for Diesel fuels to become jelly-like. The point at which they cease being a liquid is known as the pour point. This fuel quality should be watched carefully in temperatures of 20° F or lower.

Engine Power & Power Rating.

To accurately measure the amount of power an engine can produce, a dynamometer must be used. There are various types available, the simplest of which is probably the water dynamometer. One which we use extensively in our laboratory is a DC generator with special type cradle mounting. The generator is supported on ball bearings and the frame is free to rotate on these bearings supports through a small range. An arm extends out from the generator frame and an accurate scale is connected to that arm for measuring the amount of force exerted at that point. When the engine is rotating the generator armature, we may vary the amount of load on the engine by varying the excitation of the generator and thereby vary the amount of electricity it produces.

The amount of torque or twisting effort exerted by the engine crankshaft on the generator armature is identical to and may be measured by the torque at the arm extending from the generator frame. By knowing the distance from the center of the generator to the point at which the force on the arm is measured a constant can be worked out for use in calculating power. The constant times the force measured on the scale times the RPM of the engine gives a reading of horsepower which is completely independent of the electrical efficiency of the generator and is derived simply from mechanical measurement of the torque exerted by the engine.

The power an engine will produce is affected by temperature, barometric pressure and a very small degree by humidity. Dynamometer ratings for engines are always corrected to so-called standard conditions of 60° F and sea level barometric pressure. Rating procedures have been standardized for engine manufacturers by the Society of Automotive Engineers (SAE) and the Internal Combustion Engine Institute (ICEI). We follow these procedures when rating our engines for power.

Remember, altitude affects power by approximately a 3% loss for every 1000 feet of elevation above sea level. Thus, at Denver, Colorado, which is at 5000 feet above sea level, engines have lost 15% of their maximum power.

Temperature affects power approximately 1% for every 10° variation in temperature from 60°. Therefore, at 100° F which is 40° above the standard rating temperature maximum power would be 4% lower than the standard rating.

Humidity has a very small effect on engine power. Popular opinion attributes much better operation of automobile engines during rainy weather. There are other factors which produce this illusion.

To show more graphically the relationship of these various factors, the following power correction formula is shown. This is the one used in correcting observed dynamometer readings.

$$BHP_{Corrected} = BHP_{Observed} \times \frac{29.92}{(Bar. - e)_{Observed}} \sqrt{\frac{460 + Temp._{Actual}}{520}}$$

Where e = vapor pressure obtained from charts after measuring wet and dry bulb temperatures.

It is general practice in this country to rate engines for sales purposes at the maximum amount of power they will produce. The sales specification sheets show a maximum power curve which can be obtained from a laboratory engine and with readings corrected to the standard conditions indicated above. If an engine were operated at this power continuously, its life would be rather short. On applications where the number of hours used is moderate, it is allowable to use power up to approximately 85% of the maximum amount and still get suitable life from the engine. A curve representing 85% of the maximum power curve is termed the intermittent rating. For continuous operation, we recommend that power be limited to 75% of the maximum power. We may advise even lower power output if, besides continuous operation, the application requires extremely long life. In general, the amount of load on the engine is more important than its speed in promoting exceptionally long life. However, low speed and light load is always best.

Engine Torque & Torque Curves.

As indicated before, describing dynamometer measurement of power, the power can be calculated from the torque if the speed is known or, conversely, the torque can be calculated from the known power reading. The torque curves we show on our specification sheets are always calculated from the power curves, and, therefore, are closely related to power. The shape of the torque curve is important on many applications. It is desirable to have a torque curve which is fairly flat or gently drooping toward the low end of the speed range. At the high end of the speed range it should be approximately 10% lower than medium range in order to provide an increase in torque as the engine is pulled down in speed on heavy load. This gives the engine a good lugging characteristic. The torque curve is modified by modifying valve timing in the initial development of the engine.

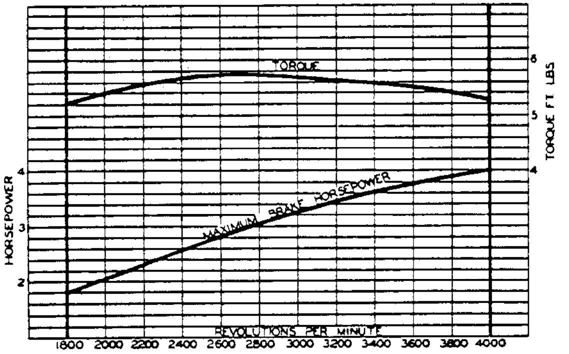


Figure 1. 13

Types of Drives.

Power is taken from engines either by means of coupling directly to the crankshaft or by means of belt and pulley or chain and sprocket types of drive. If the equipment is direct coupled, the type of coupling and the alignment between the engine shaft and equipment shaft is important. If it is direct coupled with a solid coupling, alignment must be kept within a few thousandths of an inch. If a flexible type coupling is used, some additional misalignment can be allowed but if the misalignment is excessive and the coupling flexes to a considerable degree it is possible to lose much engine power right in the coupling.

When using "V" belt drives it is important that the size of the driving pulley and belt be suitable for the amount of power being transmitted. Many times it is necessary to use several "V" belts on the larger engines. When using a chain and sprocket type of drive, the tension on the chain is of importance because there may be a whipping action due to the engine speed variation from one cycle to the next. This may be injurious to both engine and equipment, if not properly provided for. "V" belts, with their ability to stretch, act somewhat as a shock absorber and are much easier on the engines.

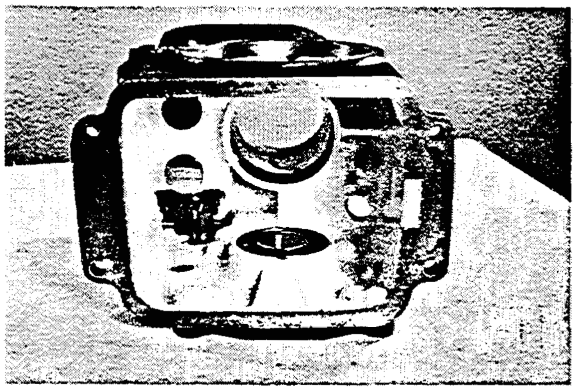
Sometimes customers require a clutch between the engine and their equipment. We can supply lever operated disc type clutches and customers frequently purchase separate centrifugal type clutches.

There is also the requirement for a reduction in rotating speed. We supply gear reductions for this purpose. In working with such a gear reduction it should always be kept in mind that engine torque is multiplied by the same ratio as the speed is reduced. With a chain and sprocket type drive on a gear reduction, firmness of engine mounting becomes essential. If the chain is directed out to the side of the engine, the torque tends to twist the engine and may show up as loosened mounting cap screws or loose screws between the engine block and base. We can also supply combination clutch and reduction units on our larger engines.

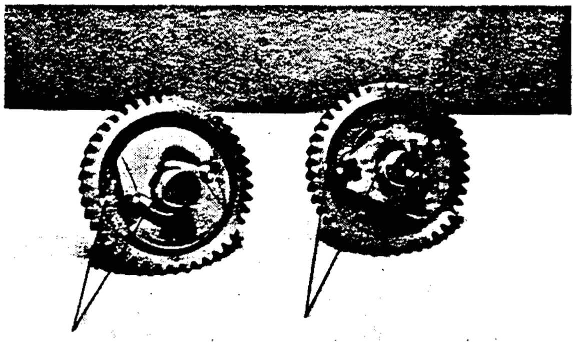
CHAPTER TWO

ASSEMBLY OF KOHLER SINGLE CYLINDER ENGINES

These illustrations show the sequence of assembly of a single cylinder Kohler engine. The engine used here was specially prepared to better show the components. When actual work is being performed, always refer to the Engine Service Manual.

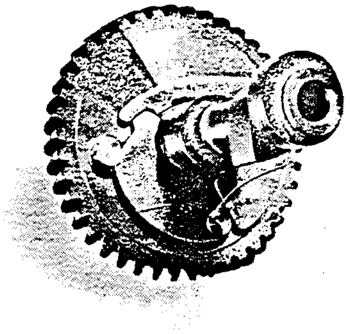


1. Install the rear main ball bearing by pressing it into the cast iron cylinder block. If bearing is shielded place shield facing inside. Install internal governor parts by referring to service manual. Install tappets.

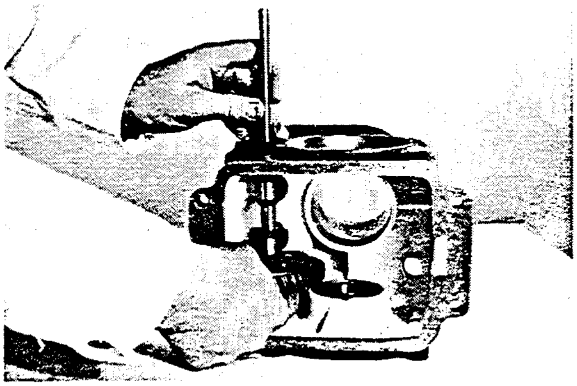


2. This illustration shows two types of spark advance systems. The standard mechanism is shown on the left and the magneto alternator spark advance system is shown on the right. Be sure the spark timing marks on cam and spark advance side of camshaft gear coincide. Marks on gears and shafts may be seen on the left-hand side of each component.

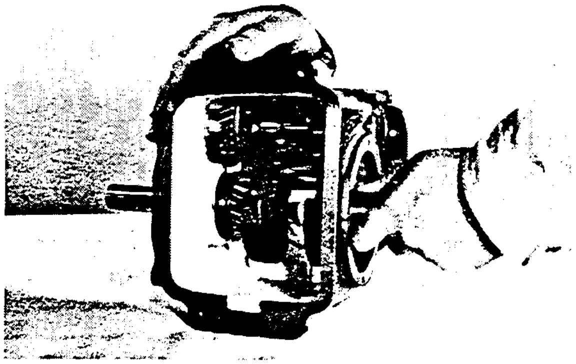
3. The Automatic Compression Release camshaft is shown in this illustration. This assembly has a cam lever which raises the exhaust valve slightly during the compression stroke enabling easy starting. Flyweight action disengages this cam lever after a speed of 650 RPM is attained. Any engine equipped with an Automatic Compression Release camshaft does not require a spark advance mechanism. This cam has been standard on all 6, 7, 8, 10 and 12 horsepower engines since mid 1965.

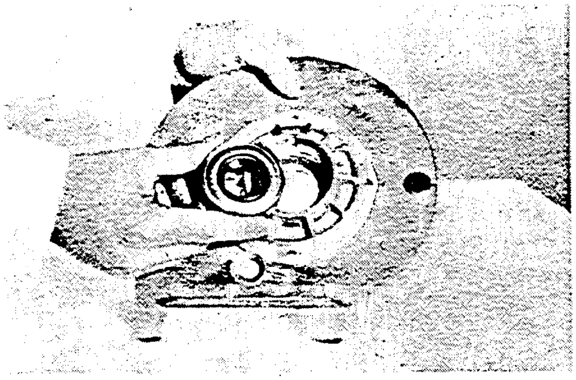


4. Install camshaft by sliding camshaft pin through block from bearing plate side and through center of camshaft. Be sure to hold breaker cam in place when installing camshafts with spark advance systems. Drive pin flush with surface of block. Shims must be used for proper end clearance.

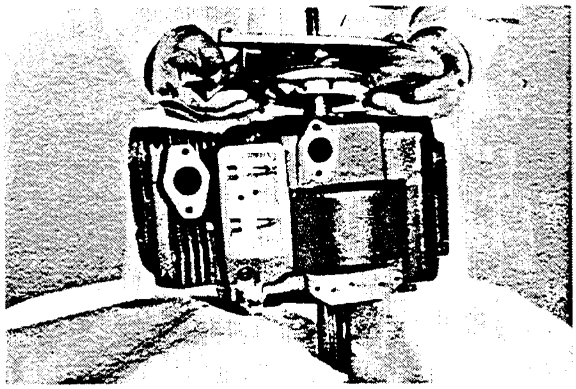


5. Install crankshaft in cylinder block. Timing marks on camshaft gear should coincide with mark on crankshaft gear. Note gear markings on camshaft and crankshaft.

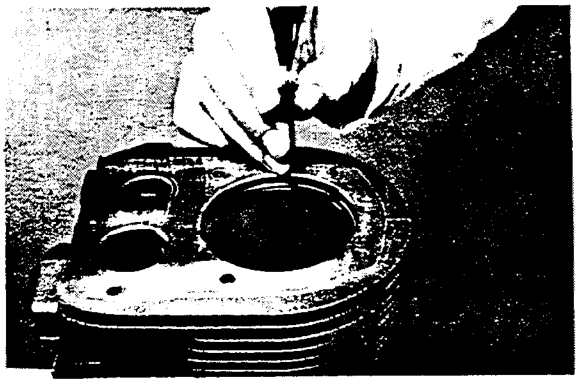




6. Press ball bearing into bearing plate. If bearing is shielded, install shielded side up.

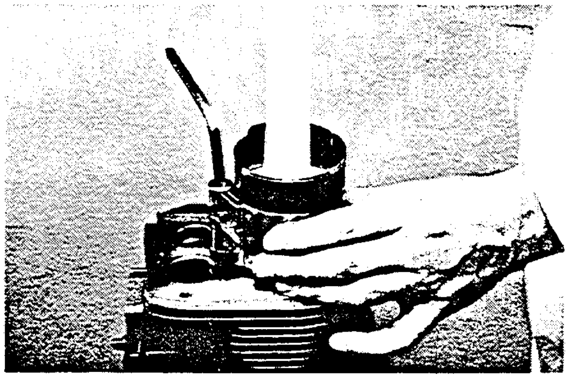


7. Install bearing plate and gasket. Use 4 cap screws with copper washers and draw up tight. Copper washers act as oil seals. Crankshaft end clearance should now be checked and compared with specifications in the manual. Install additional gaskets if necessary.

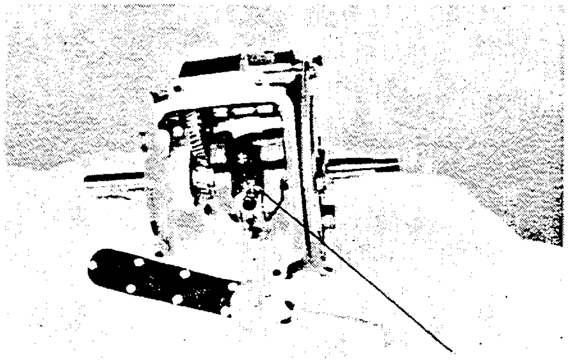


8. Check piston ring end clearance by inserting ring into cylinder bore. Be sure it is in ring travel area. Check end clearance with a feeler gauge. This gap should be from .007 to .017. Always install piston rings according to instructions given with ring sets.

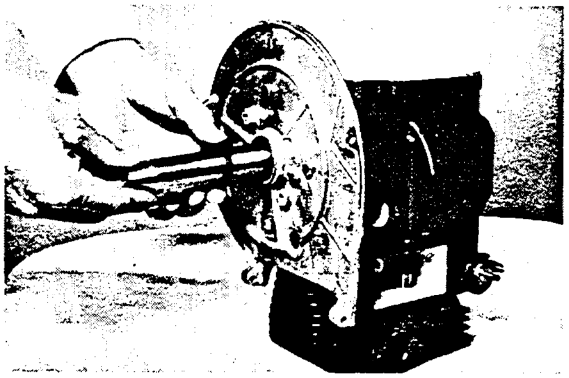
9. After oiling complete assembly, stagger ring gaps and install piston using a ring compressor. Push piston with hammer handle--DO NOT HAMMER.

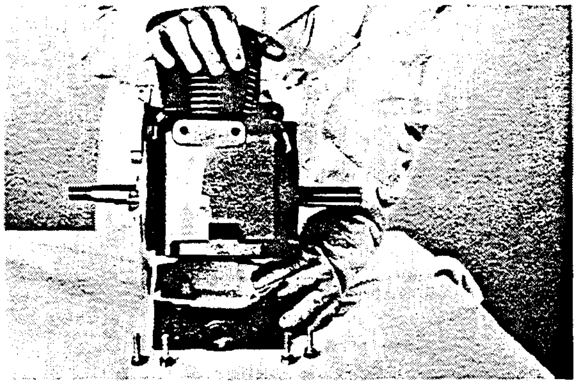


10. Connecting rod cap, lock and cap screws should be attached to connecting rod. Be sure that marks on connecting rod and cap line up and face flywheel end of engine. Note the white match marks in the illustration. Use a torque wrench to tighten cap screws according to instructions given in service manual.

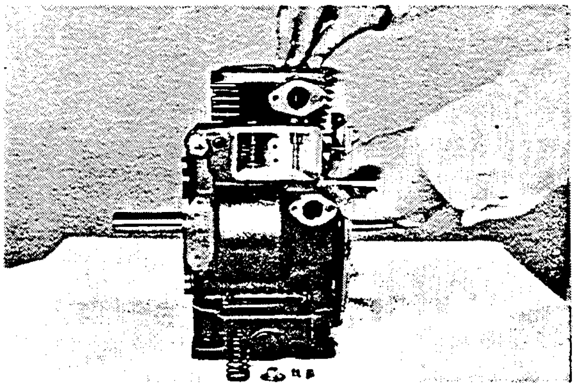


11. Install oil seals on crankshaft taking care to prevent damage to lips of seal.

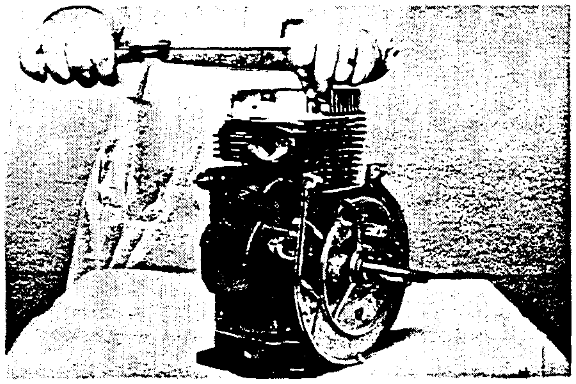




12. Assemble oil base and gasket to block with 4 screws and tighten.

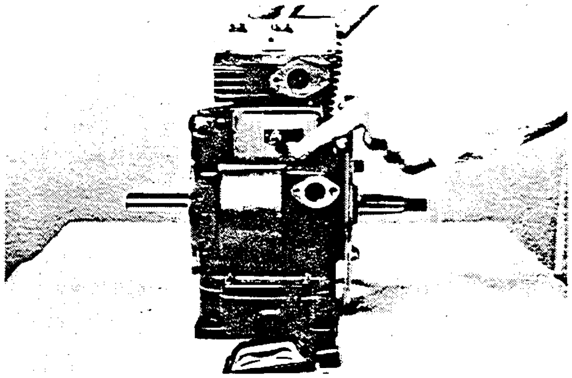


13. Install valves and check valve clearance. Be sure crankshaft is in proper position (top dead center on compression stroke). After correct clearance is obtained, install valve springs and retainers. Compress springs and place locking key in grooves of valve stems.

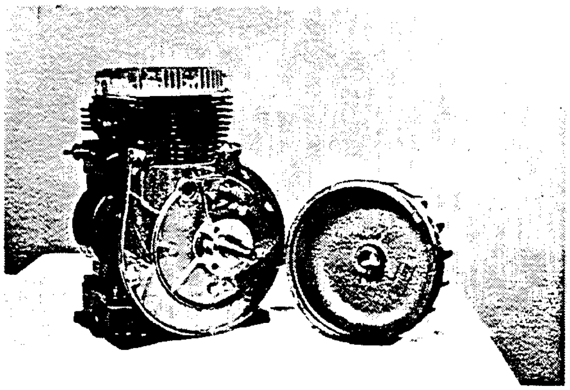


14. Install cylinder head and gasket. Always use a new gasket when head has been removed. Tighten head screws with washers evenly and in steps with a torque wrench to recommended torque as indicated in manual.

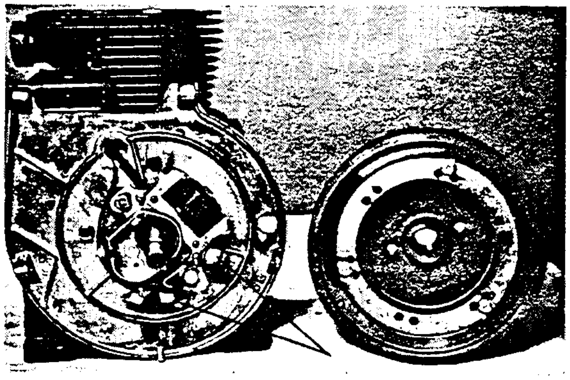
15. Install breather assembly being sure small drilled hole is in bottom of plate and reed valve faces out. This reed valve is neccessary to maintain a partial vacuum in the crankcase. If this vacuum were not present oil would leak from the crankcase.

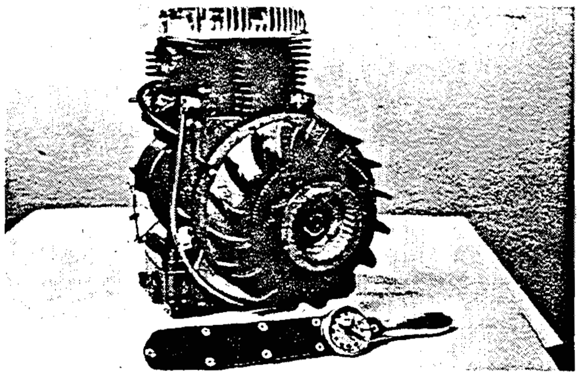


16. Install magneto on bearing plate and rotor on crankshaft.

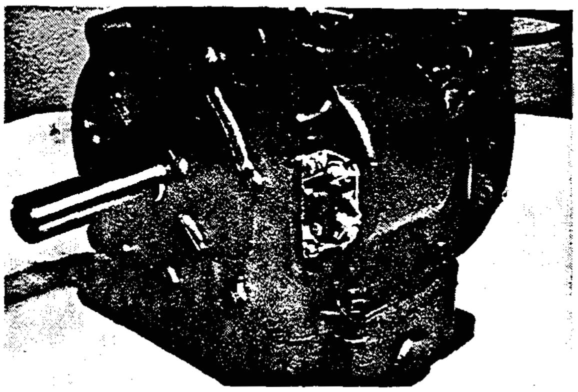


17. This illustration shows the magneto alternator. Note the two small lighting coils below and to the right of the crankshaft. The alternator produces 12 volt A. C. current for vehicle lights. This system uses a magnet ring mounted in the flywheel rather than a rotor on the crankshaft.

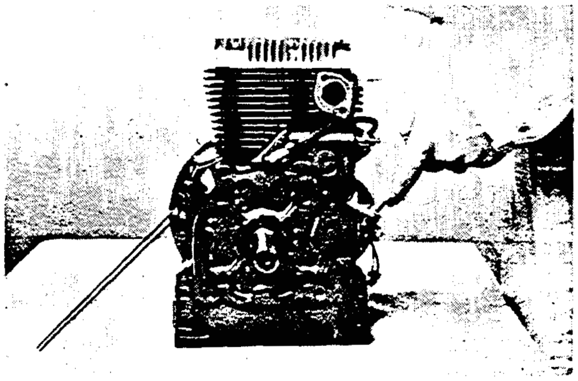




18. Install flywheel and starter pulley on crankshaft. Insert a bar between flywheel fins and torque holding nut to recommended foot pounds.

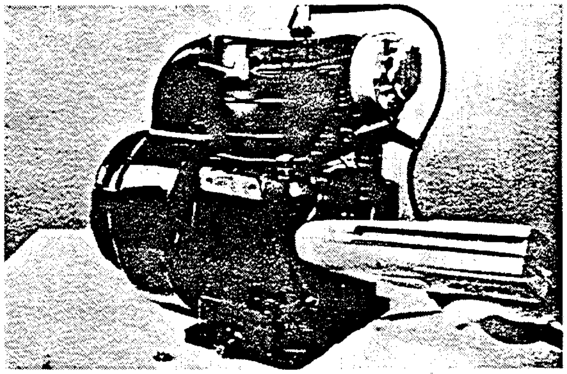


19. Install breaker push rod in hole in block and fasten breaker assembly in place with 2 screws Note that the breaker points are mounted externally on Kohler engines.

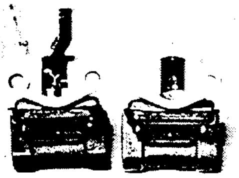


20. Set breaker point gap at .020 fully opened. For precision ignition setting use timing light at the sight hole as shown on the left side of the engine. Note timing marks.

21. This illustrates use of timing light for the final ignition timing. Use the "SP" mark with engine running. Chalk the mark to make it easier to see.



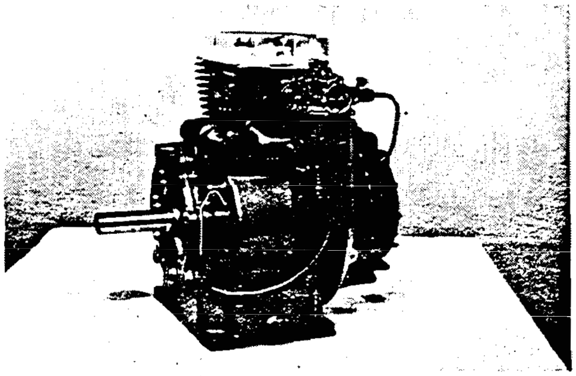
22. Install the fuel pump on the pad provided. Two types of fuel pumps are used--the pump on the left is mechanically actuated by a cam--the pump on the right is actuated by the variations in crankcase vacuum. The vacuum pump will lift fuel no higher than from the base of the engine to the carburetor and therefore is used with a gravity flow system. It is used for vehicle operation over rough terrain.



23. Assemble the carburetor components. Clockwise, starting at the top, they are - 1. Carburetor body. 2. Bowl gasket - note the splash baffle in this gasket. 3. Float valve seat. (Note: in latest carburetors valve seat is not removable.) 4. Float valve needle. 5. Float pin. 6. Float. 7. Idle jet screw. 8. Main jet screw. 9. Fuel bowl screw. 10. Fuel bowl.

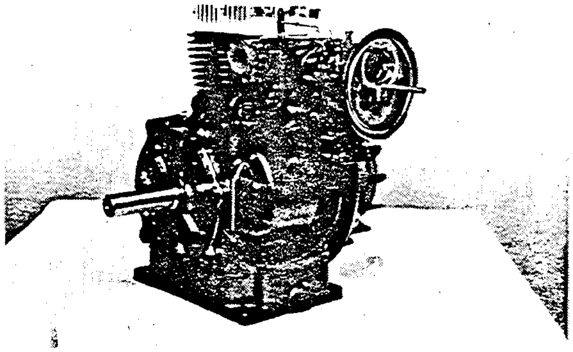
24. Set the carburetor float level as shown using the clearances given in the manual.

25. This illustration shows the up-draft carburetor used on the K141 engine. Main jet screw is on bottom of bowl--idle jet is on top left.

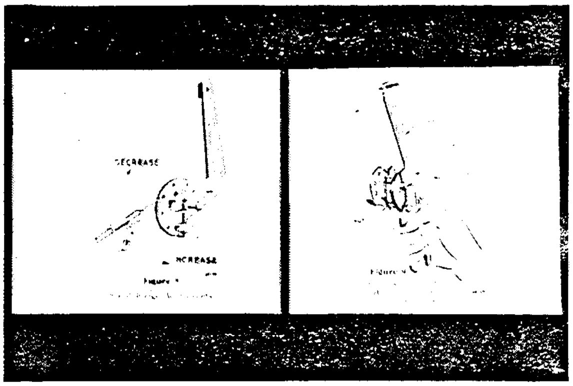


26. Install carburetor and fuel lines on cylinder block.

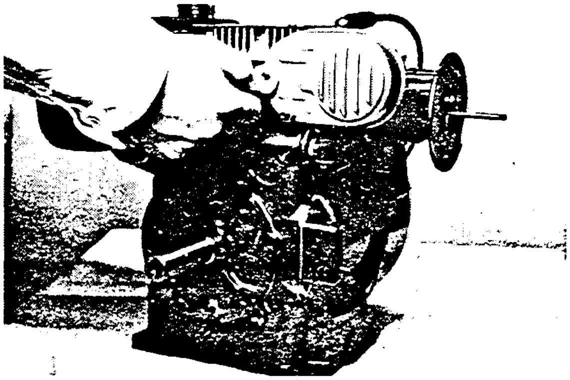
27. Install governor arm and linkage. This view shows the governor as used on the K91 through the K181. For this governor settings see the service manual. Add air-cleaner base.

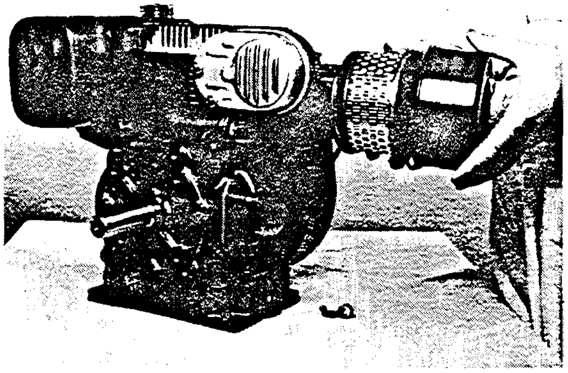


28. To adjust governor before tightening clamp bolt, turn shaft counterclockwise as far as possible using a pair of pliers. Pull arm as far as possible to left (away from carburetor). Note: The length of travel of the governor arm must equal the length of travel of the throttle arm or the governor will not work. Tighten nut and check for freedom of movement. To increase or decrease top speed, change position of throttle bracket as shown. Caution: Do not over-tighten bushing nut. Again, see the service manual for other models.

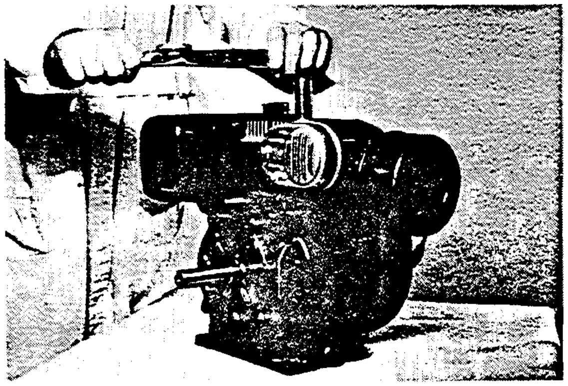


29. Install sheet metal shrouding, fuel tank, and muffler.

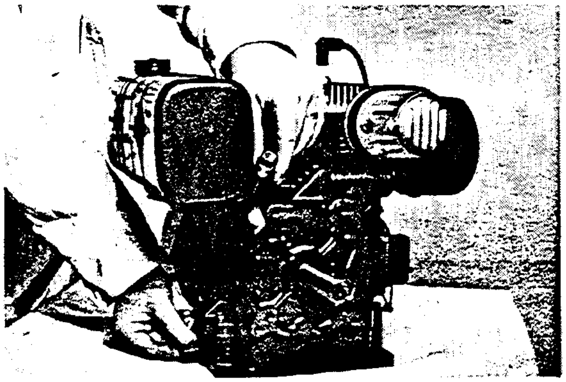




30. Install air-cleaner carefully. The dry type air-cleaner is standard equipment on all Kohler single cylinder engines. Be sure washer is installed under wing nut. When replacing elements, be sure back plate and cover offer flat surfaces so that no air can enter except through the filter element.

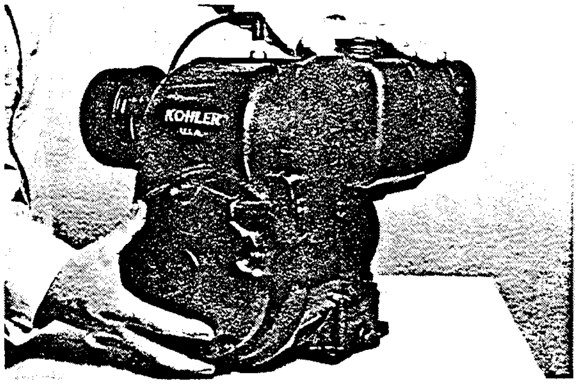


31. Install spark plug and torque to 27 ft. lbs.

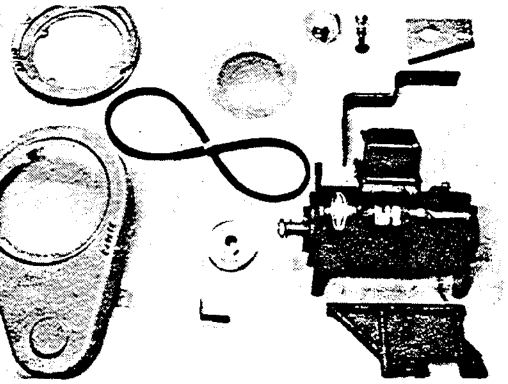


32. Install dipstick and drain plug.

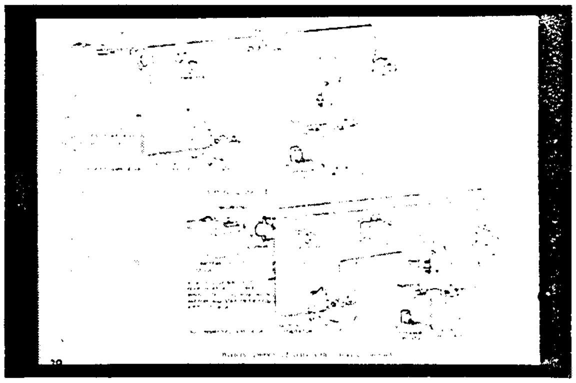
33. Position retractable starter on blower housing and tighten screws.

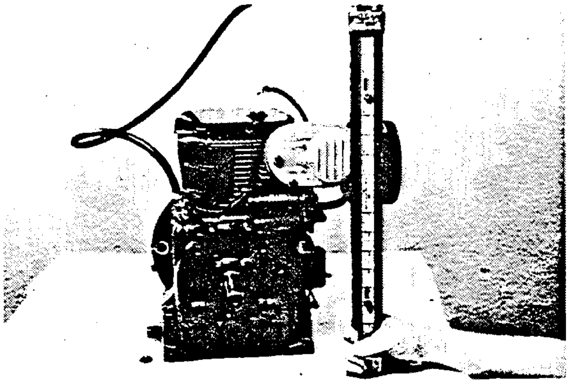


34. Some applications use electric starting. The standard electric starting components are shown in this view. Clockwise from upper left corner- 1. Flywheel pulley. 2. V-belt. 3. Air intake screen. 4. Starter switch. 5. Ignition switch. 6. Switch panel. 7. Upper starter bracket. 8. Starter-generator with voltage regulator. 9. Lower starter bracket. 10. Spacer bracket. 11. Starter-generator drive pulley. 12. Belt guard.



35. Two basic types of electric start systems are used. The top view uses a start switch while the bottom uses a starter solenoid.





36. The crankshaft breather maintains a partial vacuum in the crankcase. This vacuum should be checked occasionally with a water manometer or vacuum gauge inserted at the oil filler hole. A vacuum of 5" to 10" water column or 1/2 to 1" mercury should be present when engine is running. Lack of vacuum indicates a faulty breather, excessive engine blowby, leaky valves, or worn oil seals.

TECHNICAL INFORMATION SERIES

ENGINE

Principles of Operation and Assembly	T.I. Series No. EN-1
Magneto Ignition Systems	T.I. Series No. EN-2
Gaseous Fuel Systems	T.I. Series No. EN-3
Battery Ignition and Electrical Systems	T.I. Series No. EN-4

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TECHNICAL INFORMATION

KOHLER
ENGINES
IN Action

ENGINE

MAGNETO IGNITION SYSTEMS

KOHLER CO. - KOHLER, WIS.

CONTENTS

ENGINE

THE MAGNETO IGNITION SYSTEM

The function of an engine's ignition system is to provide, at precisely the right instant within each engine cycle, voltage of sufficiently high value to bridge the spark gap and ignite a highly compressed mixture of air and fuel.

When we consider the relatively low voltage source and the fact that from 5,000 to 20,000 volts are necessary to bridge an average spark gap of .025, we realize the important job an ignition system must perform.

The rate at which this high voltage spark must be delivered is also very impressive. Take for example, a single cylinder, four stroke cycle engine operating at 4,000 RPM. Since it takes two complete revolutions of the crankshaft to complete one cycle, the ignition spark must be delivered 2,000 times per minute.

A magneto can be thought of as a type of generator which converts mechanical energy to electrical energy through the process known as electromagnetic induction. In operation, the permanent magnets of a magneto establish a magnetic field which induces current to flow in the systems low voltage primary circuit. In the induction coil, other forms of this same principle, called self inductance and mutual inductance are used to induce the high voltage necessary to fire the spark plug.

A review of the basic fundamentals of electricity and magnetism as related to the magneto ignition system will further our understanding of the various systems used on Kohler engines.

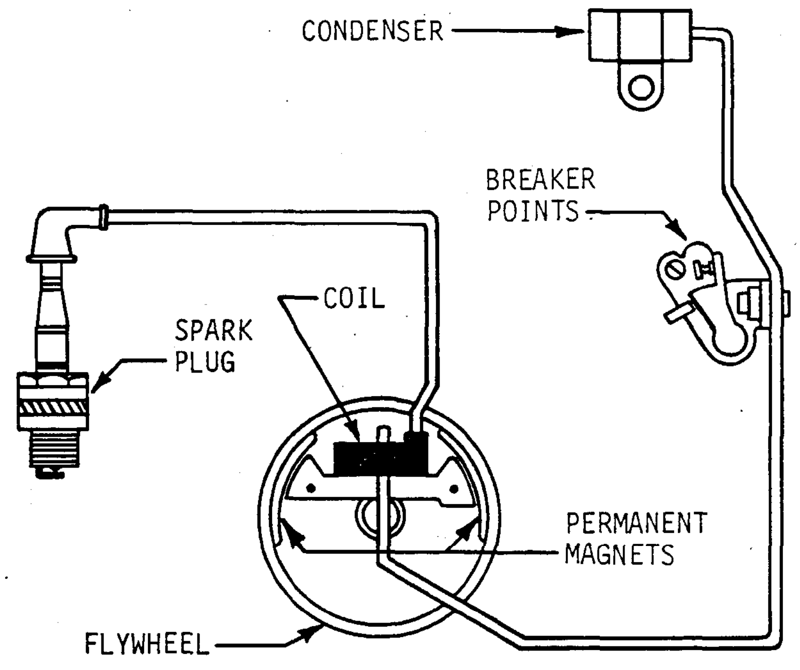


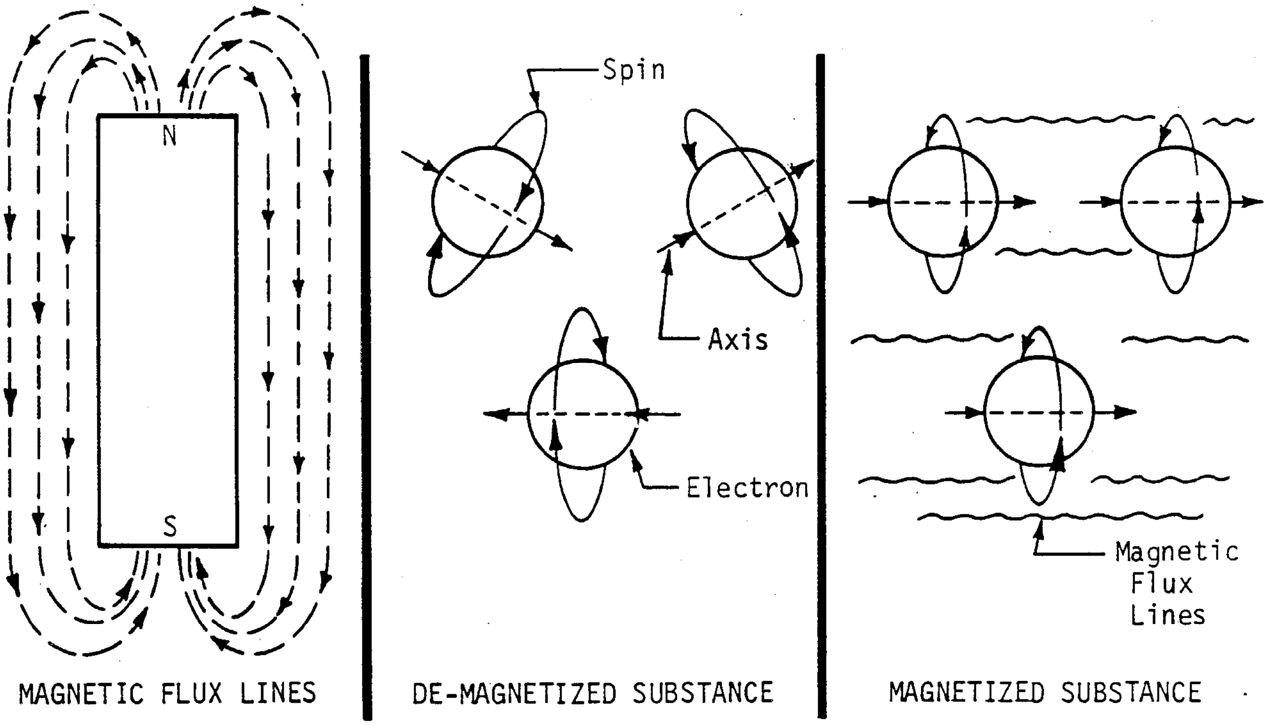
FIGURE 1 - TYPICAL FLYWHEEL MAGNETO IGNITION SYSTEM

Magnetism - Magnets

Today much is known about the behavior patterns of electricity and magnetism. However, the reason for this behavior remains somewhat of a mystery and can only be explained by theory. Without knowing exactly what electricity and magnetism are, we do know that they are closely related and that electricity can be used to produce magnetism and magnetism can be used to induce a flow of electricity.

As mentioned earlier, permanent magnets are used to induce flow of electrical current in a magneto ignition system. Before attempting to explain how they are used, let's first take a look at the characteristics of magnets.

There are two classifications of magnets. Natural magnets are substances which possess natural magnetic properties. Artificial magnets are materials in which magnetic properties can be electrically induced. The space surrounding a magnet is permeated by magnetic lines of force which are concentrated at two points--the north and south poles. In theory, these invisible lines of force, called flux, are directed away from a magnet at its north pole, travel in a loop and re-enter the magnet at its south pole. These flux lines form definite patterns which vary in density according to the strength of the particular magnet. The region surrounding a magnet at which its magnetic influence is effective, is referred to as its magnetic field.



MAGNETIC FLUX LINES | DE-MAGNETIZED SUBSTANCE | MAGNETIZED SUBSTANCE

FIGURE 2 _ MAGNETIC FLUX - ELECTRON SPIN

Magnetic induction causes an artificial magnetic substance to become a magnet when it is brought under the influence of a magnetizing force. Retentivity is the power of a magnetic substance to retain its magnetism when the magnetizing force is removed. On the other hand, permability of a substance is an indication of the ease with which magnetic lines of force can be established in the substance.

A magnetizing force can be produced electrically. We know that whenever current flows through a conductor, magnetic lines of force are created at right angles to this conductor. If a conductor is formed into a loop or coil, the magnetic lines of force become concentrated toward the inside of the loop. If we insert a substance having magnetic properties into the center of this coil, the magnetic lines of force surrounding the conductor become concentrated within the substance and the substance itself becomes magnetized through the process known as electromagnetic induction.

Some substances will lose magnetism as soon as the current is removed from the conductor. Other substances have the ability to retain magnetism long after the magnetizing influence is withdrawn. To further explain this, let's take a look at the recently introduced electron "spin" theory of magnetism.

This theory states that each electron spins on an individual axis just as the earth rotates on its axis of north and south poles. And just like the earth, each electron has a magnetic field with south and north poles. In a de-magnetized substance, the axes are pointed in helter-skelter direction as shown in figure 2. When a magnetizing force is introduced, the axes align themselves in the same direction and the individual fields combine to form a strong magnetic field which surrounds the substance. In less dense substances, the axes return to the unorganized or helter-skelter pattern as soon as the magnetizing influence is withdrawn and the substance is quickly de-magnetized. On the other hand, in the greater density substances the axes remain in alignment and the substance retains magnetic properties long after the magnetizing influence is withdrawn. The less dense substances have low retentivity while the greater density substances have high retentivity and are classified as permanent magnets. Both permanent magnets and substances of low retentivity are used in the magneto ignition system.

Magnetic Circuits

While there is no known insulator for magnetic flux, it is possible to confine and conduct flux by establishing a closed magnetic circuit. This makes it possible to concentrate flux lines where they can be best used.

Reluctance, in reference to magnetism, is roughly the equivalent of resistance in electrical circuits. Since flux lines will take the path of least reluctance, they travel easily through iron which has low reluctance. For this reason, iron is used in magneto ignition systems for the magnetic circuit.

Electromagnetic Induction

In the magneto ignition system, the magnetic field created by one or more permanent magnets is used to generate the original flow of current in the systems primary or low voltage circuit.

Whenever magnetic lines of force "cut" a conductor, an electromotive force (EMF) is induced within the conductor and if the conductor is part of a completed electrical circuit, this EMF will cause current to flow. EMF is the force or difference in electrical potential that causes electrons to flow. It is not necessary that the circuit is complete in order to establish an EMF but it must be complete to have electrical current.

As stated, the magnetic lines of force must cut a conductor. To further clarify this, the magnetic field must be increasing or decreasing in strength across the conductor to induce energy.

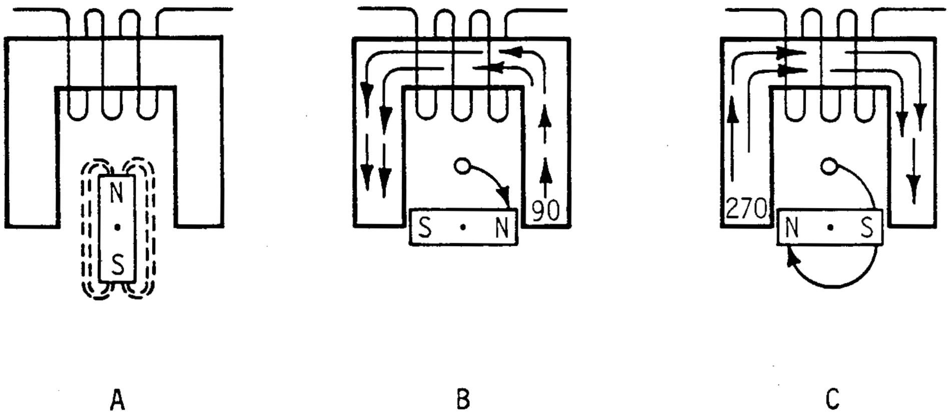


FIGURE 3 - FLUX REVERSAL INDUCES A VOLTAGE

To do this, we must have motion in the form of either stationary flux with a moving conductor or a stationary conductor with moving flux. The latter method is used in a magneto system.

The amount of current (or EMF) induced depends mainly upon the following factors; the field strength of the permanent magnets, the speed at which the conductor is cut and the area of the conductor effected by magnetic flux.

In figure 3 we show a simple magneto in which a single bar type permanent magnet is rotated within an inverted "U" shaped core. A conductor is wound or coiled around the upper part of the core. In position A, no current is induced since the magnetic field has no effect on the core but as the magnet is rotated 90°, as shown in position B, flux is conducted through the core in a direction from right to left and an EMF is built up in the coil. Further rotation of another 180° to the position indicated as C causes another flow of flux through the core, however, in this position the direction is reversed and it now travels from left to right. This reversal is very important to the function of a magneto since it is at this instant that maximum EMF is achieved.

Self Inductance

Since the primary coil in a magneto system is part of a normally closed or complete electrical circuit, the induced EMF causes current to flow in the circuit. Here another form of inductance, called self-inductance is utilized to intensify and momentarily sustain the electrical energy in the primary.

Whenever current flows in a conductor, a magnetic field is created around the conductor. This field forms as concentric or circular lines of force at right angles to the conductor. It expands outward with increase in current and contracts inward toward the conductor with decrease in current.

If the conductor is wound in a coil, the field created around each loop links magnetically with adjacent loops whenever the current changes in value. This self-induced field creates an

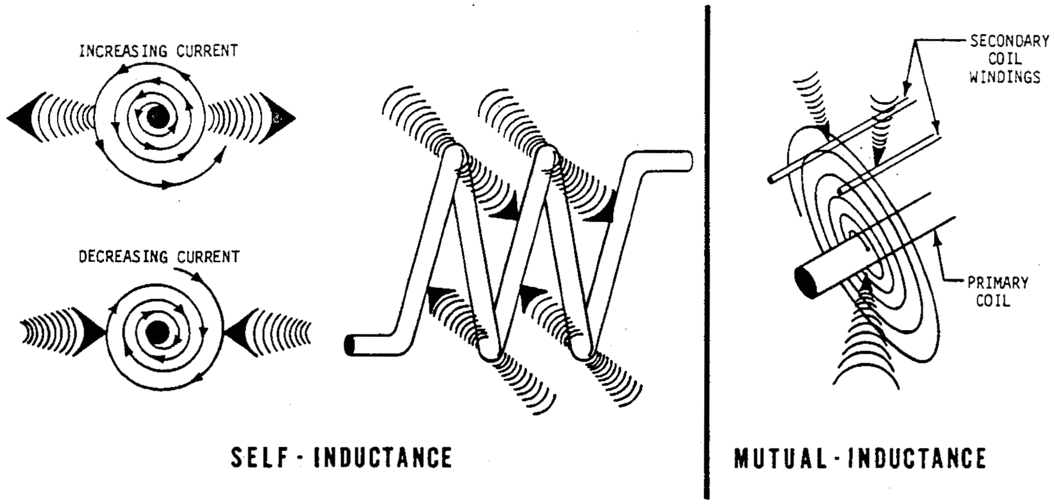


FIGURE 4 - OPPOSING FLUX CREATES COMBINED FIELD

EMF that opposes any change in current. Although it tends to provide a choking effect with increasing current, an abrupt halt in current flow causes the collapsing field of each loop to cut adjacent loops thereby inducing an EMF which creates another surge of current that is many times greater in value than the original current induced by motion of the magnetos past the coil. The current produced in the primary is unidirectional but pulsating direct current.

Mutual Inductance

Still another form of inductance is used to create the high voltage current necessary to jump the spark gap. If we place a second coil in close proximity to the primary coil, the self-induced magnetic field surrounding the primary also links magnetically with this second coil. Since this secondary coil is part of a normally open circuit in a magneto an EMF is built up in the coil through mutual inductance from the neighboring primary coil.

When current in the primary reaches approximately maximum value, the circuit is "broken" which causes a rapid collapse of the self-induced magnetic field. This rapidly collapsing field "cuts" each turn of the secondary winding and an EMF is built up in the secondary coil. In an ignition system, the secondary coil may have up to 100 times as many turns as the primary coil. This is important since the ratio of turns in the primary to those in the secondary determines the ratio of voltage "step-up" between the two. In other words, if 200 volts are induced in the primary, 20,000 volts could concieveably be imposed in a secondary having 100 times as many turns. In the ignition system, the EMF builds up only to a value sufficient to ionize or bridge the spark gap. When this occurs, the secondary circuit is complete and the resulting surge of high voltage energy across this gap ignites the fuel-air mixture.

BASIC COMPONENTS

Before attempting to explain the operation of a magneto ignition system, it may be helpful to briefly review the basic construction and individual function of the major components.

Permanent Magnets

The permanent magnets used are substances which feature high magnetic strength and the ability to remain highly magnetized for indefinite periods. The function of the permanent magnet is to provide the strong magnetic field which is required for induction of the low voltage primary current.

Coil--Core Assembly

The coil consists of two separate windings which are wound around a laminated iron core. This assembly is often referred to as the high tension coil. The function of this coil is to transform or step up the low voltage generated by the reversal of the magnetic field into the high voltage necessary to jump the gap of the spark plug.

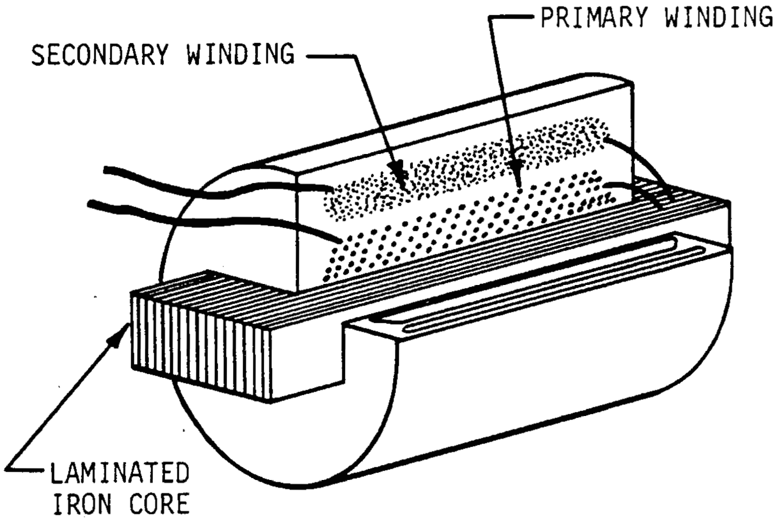


FIGURE 5 - TYPICAL HIGH TENSION COIL

The ignition coil contains three essential parts, a primary winding consisting of a few hundred turns of relatively heavy wire, a secondary winding consisting of many thousand turns of very fine wire, and a laminated soft iron core which serves to concentrate the magnetic field. The coil assembly is carefully insulated to minimize the adverse effects of heat and moisture.

One end of the primary coil is grounded to the core while the other is connected to the breaker points. One end of the secondary is also grounded to the core and the other connected to the plug high tension lead.

The iron core used in the high tension coil is constructed of a series of laminations rather than a solid piece. If a solid piece were used, a large eddy current would be induced in the core and consequently the reversal of magnetic flux would be resisted. The small amount of oxidation that exists on each lamination acts as an insulator and prevents eddy currents from passing from one lamination to another.

Eddy currents are extraneous currents produced when magnetic flux flows through the core. The changing magnetic field through the core not only induces an electrical current in the primary winding but it also induces small circulating currents which are undesirable as they build up heat and actually tend to oppose the necessary reversal of the magnetic flux through the core. Since these eddy currents are proportional to the square of the core thickness, it follows that by dividing the core into many thin laminations the eddy currents are kept to a minimum.

Breaker Points

The breaker point assembly consists of two tungsten points which are mounted on a bracket. Tungsten is used because it is an extremely hard metal with a very high melting point and is able to withstand the continual pounding of the points closing and the erroding effect of the arc that forms when the points begin to open. On Kohler engines this assembly is externally mounted for ease of service and is enclosed in a metal cover to protect it against dust and moisture. The points are spring held in a closed position to provide a complete electrical circuit for the ignition system primary and are activated by the action of a breaker rod that rides on an ignition cam driven by the engine.

When the ignition spark is desired, the points are opened to break the flow of current in the primary. This causes the collapse of the magnetic field in the ignition coil which in turn induces the high voltage necessary to fire the spark plug.

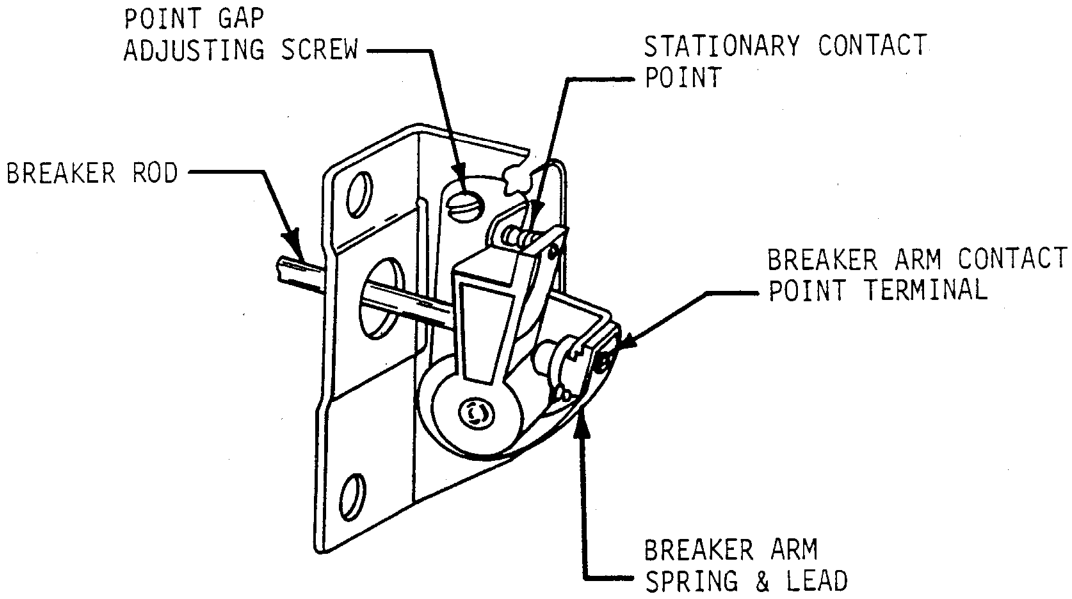


FIGURE 6 - TYPICAL IGNITION BREAKER POINTS

Condenser

The condenser also performs a very important function. If it were not for the condenser, which is connected across the breaker points, current would continue to flow between the points as they separated. This current would form an arc which would burn the points badly and would also drain away most of the magnetic energy stored in the ignition coil. There would be insufficient energy left in the coil to produce the necessary high voltage surge in the secondary.

The ignition condenser provides a place where the current can flow during the first instant the points begin to separate. The energy is absorbed by the condenser instead of forming an arc between the separating points. A definite amount of energy is needed to produce the arc. A condenser must be selected that has just enough capacitance to absorb this amount of energy. A condenser with over-capacitance will cause a weaker spark to be produced while one with insufficient capacitance would obviously not be able to prevent the arc. The condenser thus acts as a storage chamber for the electrical energy.

The construction of the ignition condenser is very simple. Two strips of aluminum foil of a predetermined length are wound together within insulating strips which separate them. One strip of foil is grounded to the container while the other is connected across the ignition breaker points.

The condensers ability to absorb electrical charge can best be explained by the electron theory. The foil strip connected across the points absorbs the flow of electrons as the breaker points begin to separate and in so doing builds up a strong negative charge. The insulation (di-electric) separating the two strips, blocks the flow of electrons between the strips. The electrons bound to the atoms within the di-electric are repelled and distorted out of their normal orbit, that is, they move away from the like charges of the negatively charged strip and move closer to the other strip. In so doing they force electrons out of this strip causing it to become positive in charge. A difference in electrical potential or voltage is therefore built up between the strips. A condenser will allow current to flow only while the strips build up a charge which is only momentarily. After the condenser is fully charged and the primary voltage drops, it discharges back through the primary circuit.

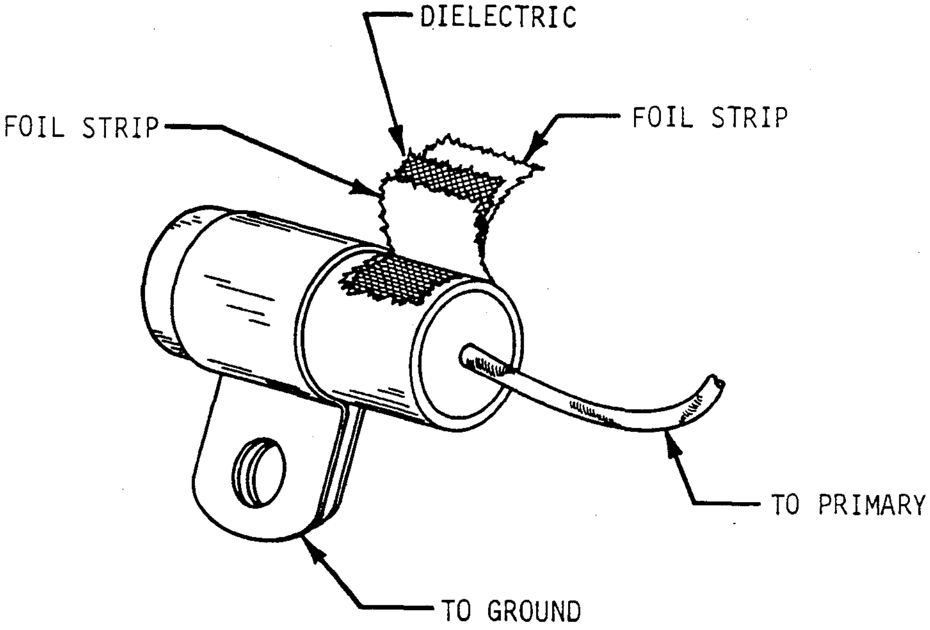


FIGURE 7 - TYPICAL CONDENSER

High Tension Lead

The high tension lead provides a path for the high voltage current to travel from the secondary coil to the spark plug. Its core is a conductor surrounded by a heavy layer of insulation. On some applications a metallic covering is used to contain the high frequency waves eminating from the system and thereby suppresses radio interference.

Spark Plug

The spark plug is used to ignite the compressed fuel-air mixture in the engines combustion chamber. A typical spark plug consists of a shell, a ceramic insulator, a center electrode and a ground electrode. The two electrodes are separated by an air gap. The path of the high tension electricity is through the terminal down through the center electrode, across the gap to the ground electrode. The condition of the electrodes and the proper spark gap is essential to operation of an engine.

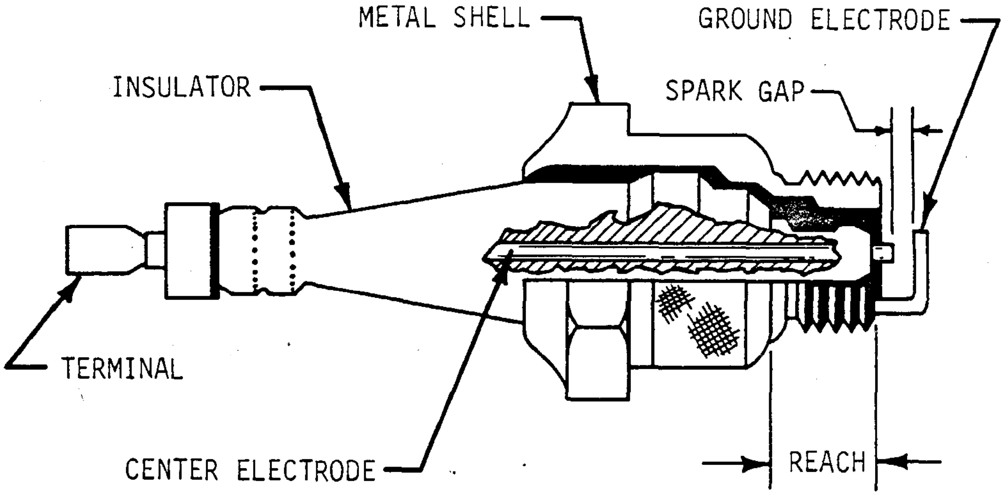


FIGURE 8 - TYPICAL SPARK PLUG

MAGNETO CYCLE

In the foregoing we reviewed the individual function of the basic components of the magneto ignition system. With this as background, we can now trace through a complete magneto cycle to see how each component contributes to the overall function of the ignition system.

While several different magneto types are used on Kohler engines, we will illustrate the operation of a flywheel magneto on a single cylinder engine. On this type, one or more permanent magnets are affixed to the inside rim of the flywheel and rotate around the coil assembly which is mounted in a fixed position on the engine.

In a flywheel magneto illustrated in Figure 9, the magnetic flux flows in one direction through the center leg of the core as the north pole of the magnet rotates adjacent to it, then reverses its direction as the south pole rotates adjacent to the center leg as shown in the right view. Whenever flux flows through the core, electricity is induced in the primary winding of the coil. At the instant of reversal of the magnetic field through the core, the induced current reaches its maximum. At this same instant the engine should be on its compression stroke with the piston nearing the top of the cylinder.

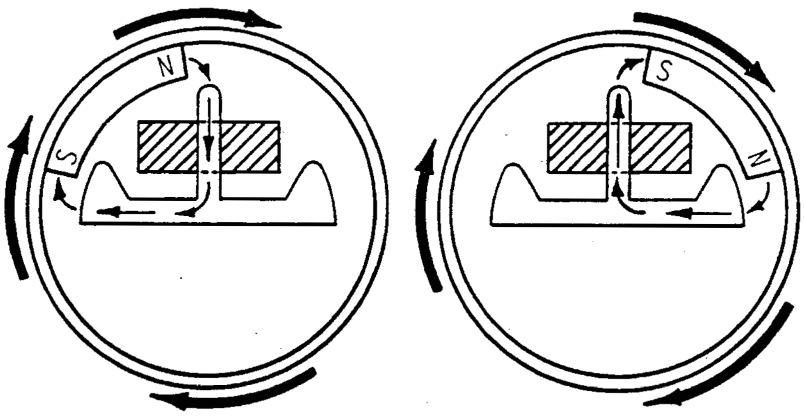


FIGURE 9 - THE MAGNETO CYCLE

Spark timing is very essential here. Since a brief lag is experienced between the time fuel ignites and the time it reaches its full power, it is necessary to provide the ignition spark slightly in advance of the piston reaching the top of the compression stroke.

When ignition is required, the breaker points are opened by the action of the breaker rod. This causes a halt in current flow in the primary winding of the coil, and the resulting sudden collpase of the magnetic field surrounding the coil windings. At this instant, the rapid change in the concentration of magnetism causes a voltage to be induced in every turn of both the primary and secondary windings. In the primary winding the voltage which may reach as high as 250 volts, is quickly absorbed by the condenser. The condenser thus acts as a reservoir for the surge of power in the primary coil winding. If the surge had nowhere to go it would arc across the points completing a circuit that would effect a complete breakdown of the entire function. The condenser holds this energy only for an instant after which time it is released back into the primary.

The voltage built up in the secondary, which has up to 100 times as many turns as the primary, could go as high as 25,000 volts. Normally, however, voltage does not increase to this value. It increases only to the amount sufficient to bridge the spark gap. This is usually between 6,000 and 20,000 volts. The actual value depends upon such variables as compression, speed, shape and condition of electrodes, width of spark gap, etc.

MAGNETO TYPES

Several different types of magneto systems are utilized on Kohler spark ignition engines. While they differ in construction and in physical appearance, their basic components and theory of operation remain the same. The types used can be classified under the following:

1. Flywheel Magneto Types
    - A. Flywheel Magneto Types
    - B. Flywheel Magneto-Rotor Types
    - C. Flywheel Magneto-Alternator Types
2. External Magneto Types
    - A. Simultaneous Firing Types
    - B. Distributor Alternate Firing Types

The flywheel types are generally used on single cylinder engines while the two cylinder model K662 uses the external magneto types which feature devices for imparting increased voltage at low cranking speeds.

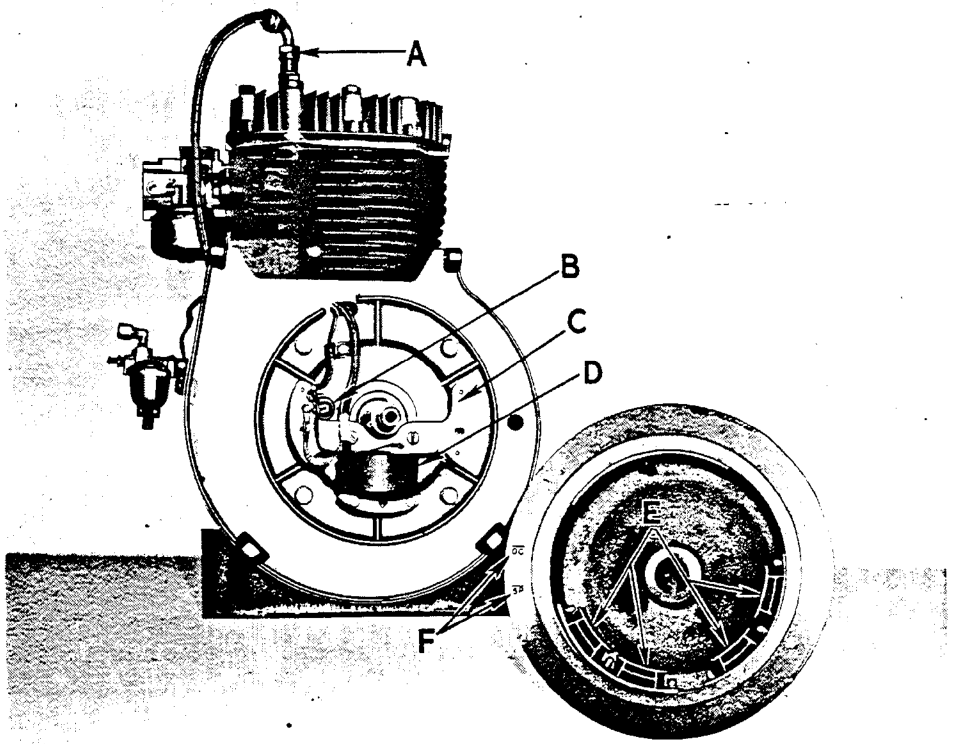


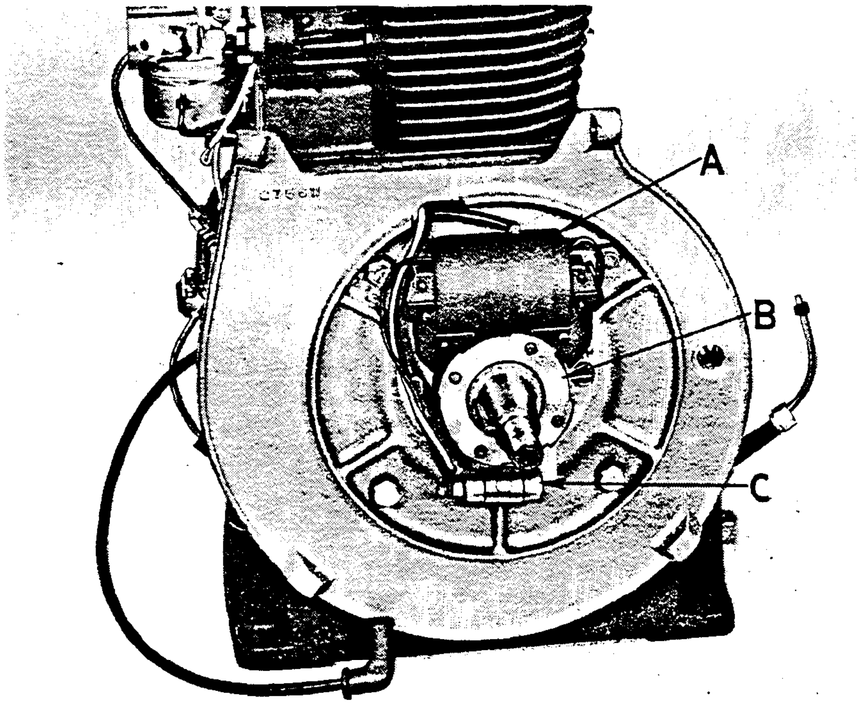
FIGURE 10 - TYPICAL FLYWHEEL MAGNETO

A-Spark Plug B-Condenser C-Core (Pole Shoes)
D-Coil E-Permanent Magnets F-Timing Marks

Flywheel Magneto Types

All Kohler flywheel magneto systems have the same basic components. They differ only in the arrangement of the permanent magnets in relation to the coil. In the foregoing section under the magneto cycle, we illustrated the operation of the type commonly used on the smaller single cylinder engines. On this system, the permanent magnets are affixed to the inside rim of the flywheel and are rotated around the stationary coil core assembly.

The other type in general use on the larger single cylinder engines is the flywheel magneto-rotor type. In this system the permanent magnets are imbedded in a rotor that is revolved within a laminated frame. This frame also contains the high tension coil. The rotor assembly is assembled to the crankshaft while the laminated frame and high tension coil assembly is affixed in a stationary position on the engine.



A-Coil B-Rotating Magnet C-Condenser
FIGURE 11 - FLYWHEEL MAGNETO - ROTOR TYPE

In cases where lighting is desired with flywheel magneto equipped engines, a magnet ring or so called alternator ring is used instead of several permanent magnets. The ring is affixed to the flywheel. The ignition coil is at the top of the stator assembly and the lighting coils are in the lower area. This system functions the same as the foregoing types, however, the magnet ring provides a nearly continuous magnetic field for induction of electrical currents in the two lighting coils.

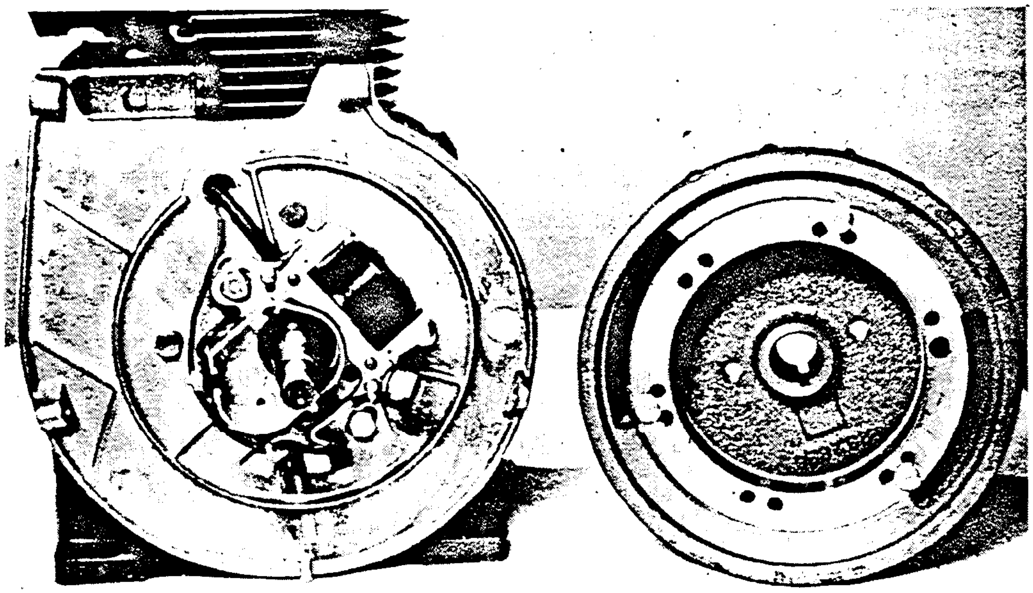


FIGURE 12 - FLYWHEEL MAGNETO - ALTERNATOR

External Magneto Types

These are self contained units, externally mounted and driven off the cam gear. The magneto rotor, mounted on the shaft contains the magnets. As the engine turns the rotor, the magnetic field through the frame changes. Since the coil is wound around the frame the changing magnetic field cuts through the coil also. Current is generated in the same general way that was discussed in the operation of the flywheel type magneto.

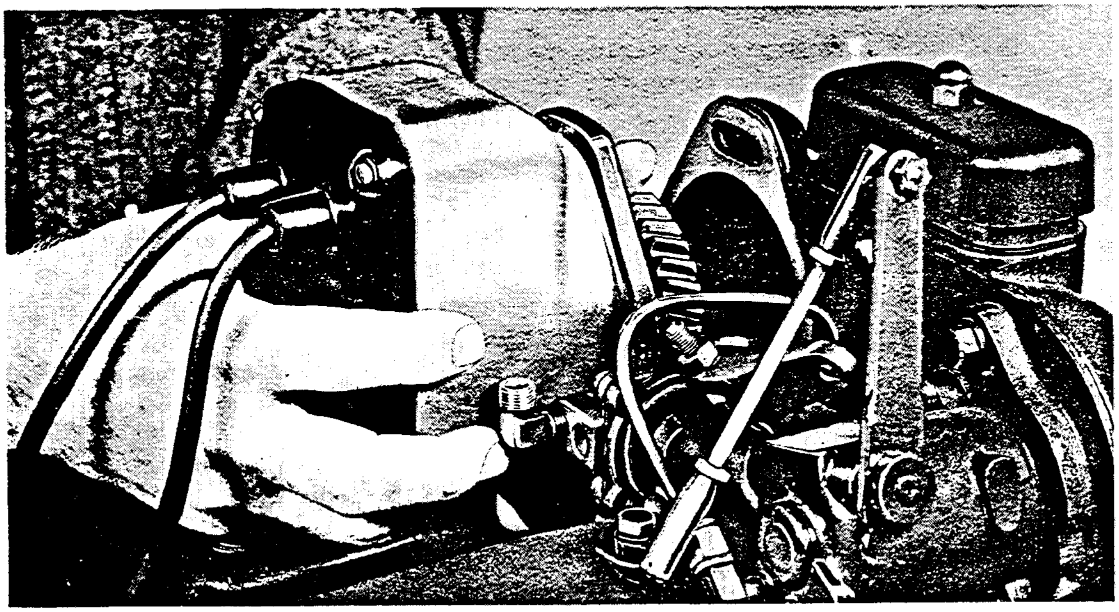


FIGURE 13 - TYPICAL EXTERNAL MAGNETO

A disadvantage of the magneto system is its weak output at engine starting speeds. One way to increase the voltage induced across the secondary coil is to speed up the rotor motion. At cranking speeds this can be done by a device called an impulse coupling. The ability to impart additional starting voltage through the impulse coupling is an important advantage of the external type magnetos.

Impulse Coupling

The impulse coupling is installed between the engine drive and the magneto proper on the majority of external magneto installations. Its primary function is to intensify the ignition spark at low speeds to facilitate engine starting. The impulse coupling functions as a mechanical reservoir to store energy.

Basically the impulse coupling consists of a shell and a hub connected together by a strong spring. One half of the coupling (the shell) is fitted to a drive member on the engine drive shaft, while the other half (the hub) is keyed to the magneto rotor shaft. In operation at slow speeds, a pawl on the magneto half of the coupling engages a stop pin mounted on the magneto frame which acts to prevent further movement of the rotor while the engine half of the coupling continues to rotate. The relative change in position winds up the connecting spring. When ignition spark is desired, the pawl is released and the drive spring permitted to snap the magneto rotor forward at high speed through its firing position. As the speed of the engine picks up, the centrifugal force acting on the pawls withdraws them in a position where they no longer engage the coupling stop pin and the impulse coupling then acts as a solid drive member.

Standard Magneto

The simultaneous firing type uses a single coil with two high tension terminals on the secondary. This type fires both cylinders simultaneously, therefore, wasting one spark since one of the cylinders is on the exhaust stroke as the other is on the ignition stroke.

Distributor Magneto

The other type is often referred to as the distributor type. A distributor is used to connect the proper spark plug to the secondary winding of the coil. The distributor works like a rotary switch. In other words, it connects the desired spark to the secondary at the proper time. In operation, each time the points open, the magnetic field around the windings collapse. At this same time, the distributor rotor is passing the proper spark plug terminal. The collapsing field around the coil develops a high voltage across the secondary winding and flows from the secondary winding through the high tension rod assembly to the distributor rotor. The high voltage path continues from the distributor rotor through one of the high tension wires to one of the spark plugs.

TIMING

Exact timing of the ignition spark is essential to efficient operation of an engine. The spark must occur at exactly the right moment in respect to the position of the piston in the cylinder. Prior to introduction of the Automatic Compression Release mechanism, it was usually necessary, at the slower starting speeds, to ignite the fuel charge immediately before or immediately after the piston reached top dead center (TDC) on its compression stroke. At the higher operating speeds, ignition must, in all cases, be started in advance of the piston reaching TDC.

The reason for this is: When ignition takes place in the combustion chamber of an engine, the result is not an explosion of the air-fuel mixture nor are the combustion pressures exerted instantaneously. On the contrary, a constant amount of time is always needed for complete combustion and during this interval of time, the pressures of the burning gases start low then build up to a maximum value at about midpoint in the process. The flame pattern originates, of course, at the spark plug electrodes, then moves outward from this point into the combustion chamber.

At normal operating speeds, optimum engine power is realized in having the maximum combustion pressures applied to the piston after it has reached TDC and has started downward on the power stroke. Since the time required for combustion remains, for all practical purposes, constant regardless of engine speed, it is necessary to ignite the fuel before the piston reaches TDC in order to realize the full force of the combustion pressures. For example, if we waited until the piston reached top dead center before starting the combustion process, the piston would be well on its way downward in its power stroke and the full force of combustion would be exerted too late to realize greatest power.

Spark Advance

Causing the spark to occur earlier in the engine cycle is called spark advance or it is referred to as the spark run setting. This is stated as the number of degrees of crankshaft rotation remaining before the piston reaches top dead center or BTDC. By advancing the spark, we are actually igniting the fuel charge while the piston is traveling upward on its compression stroke. If timing is correct, the highest combustion pressures are then reached just after the piston reaches TDC. In igniting the fuel charge while the piston is still on the compression stroke, it is apparent that some force is exerted which would oppose the upward travel of the piston. This is true; however, at operating speeds inertia provided by the flywheel overcomes this opposing force.

Fixed Timing

On engines with "fixed timing" the spark is timed to occur at a point BTDC that has been established as the most advantageous for normal operating speeds. Fixed timing is used on all present production single cylinder engines, with the exception of the K330.

Automatic Spark Advance

If no provision were made to either release compression or to retard the spark at the lower starting speeds and the ignition spark was fired at the normal spark run point, the expanding force of the burning gases would reach maximum pressure before the piston had reached the top of its compression stroke, thus a backward force would be applied to the piston. This is because the piston would travel less distance during the time required for the combustion pressures to expand to maximum. For example, at 360 RPM, piston travel would be 1/10 of what it would be at 3600 RPM.

If maximum combustion pressures are applied to this piston while it is still on its compression stroke, this can produce "kickback" which can cause serious damage to an engine. This force actually tends to oppose normal rotation of the engine and at low rotational speeds, the flywheel cannot provide sufficient inertia to overcome this force.

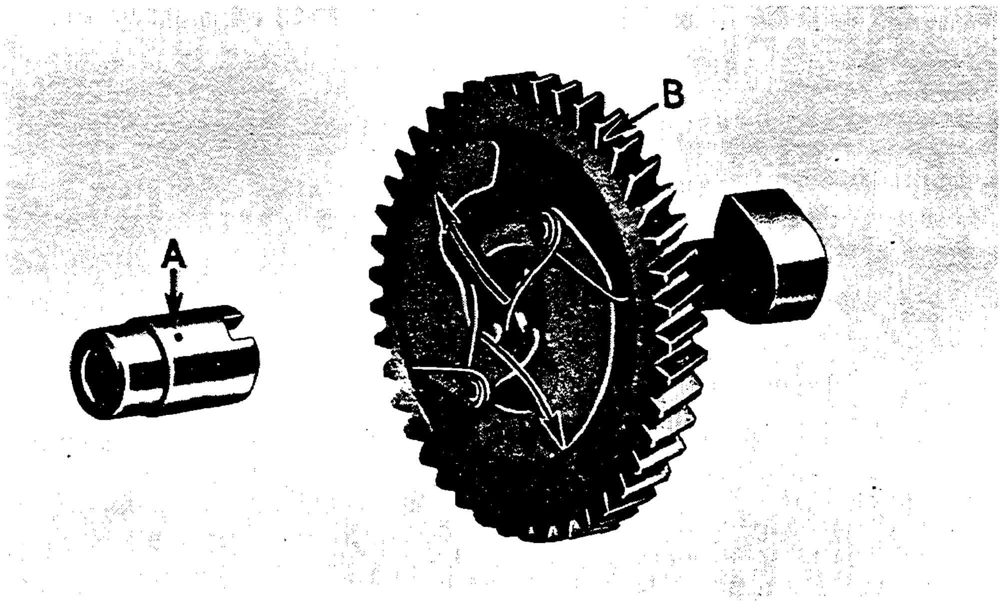


FIGURE 14 - AUTOMATIC SPARK ADVANCE CAMSHAFT

A-Movable Ignition Cam B-Timing Advance Flyweights

To eliminate kickback at cranking speeds, an automatic spark advance mechanism is used on the earlier single cylinder and on the two cylinder model K482. The exception is the K90 Series engines which have fixed timing. On these engines, the spark is automatically advanced with increase in engine speed to the "spark run" setting. This is accomplished by a centrifugal flyweight arrangement that automatically shifts the position of the ignition cam with increase in engine speed. The flyweights as shown in Figure 14 are the timing advance actuators. Ignition timing is set immediately before or immediately after top dead center at retard and as the engine starts and increases in speed to about 800 RPM, the flyweights move to the outside and advance the cam to the "spark run" setting.

Spark retard is the term used to describe ignition at a point later in the engine cycle than the normal spark run or advanced point. The confusion in this term apparently stems from the idea that any point before TDC is considered spark advance while any point after TDC is considered spark retard. On earlier single cylinder engines, spark retard was established at two or three degrees ATDC, while on the present two cylinder models spark retard is either 2 or 8 degrees BTDC. Introduction of the Automatic Compression Release mechanism on single cylinder engines has eliminated the need for spark retard. This is explained later in "Timing -- ACR Engines".

Timing Adjustment

While timing is initially established through proper positioning of the ignition cam in respect to degrees of crankshaft rotation, it is possible to alter timing to a certain degree by shifting the point at which the breaker points open. The amount of adjustment obtained in this way is definitely limited since the strength of the ignition spark diminishes rapidly as the points are adjusted to open farther away from the fixed point of maximum current flow in the primary.

The breaker point assembly is designed with one stationary contact and one movable contact. The movable contact is part of an adjustable breaker plate. By shifting this plate, the instant of point opening is changed in respect to movement of the ignition cam, and thus causes the spark to occur either earlier or later in the engine cycle, depending upon which way the plate is shifted.

There are several methods used to achieve exact timing of the ignition spark. One method is to turn the engine over by hand until the proper ignition timing mark on the flywheel appears in the timing sight hole. When this mark lines up in the sight hole, the breaker points should be just starting to open. The engine is then rotated until the maximum opening occurs and point gap adjusted to the recommended setting. This method is often used as the initial timing adjustment and a timing light is used later to achieve precision adjustment with the engine running at normal speeds.

If ignition timing is adjusted to occur too early, maximum combustion pressures will be reached while the piston is still moving upward on its compression stroke. In extreme cases, this causes severe pinging, knocking and power loss. Engine damage can also result since the temperatures of compression plus combustion combine to create abnormally high temperatures in the combustion chamber. On the other hand, if the spark is adjusted to appear too late in the engine cycle, power will be wasted since the piston may be well on its way downward in the power stroke before the maximum pressures of combustion occur.

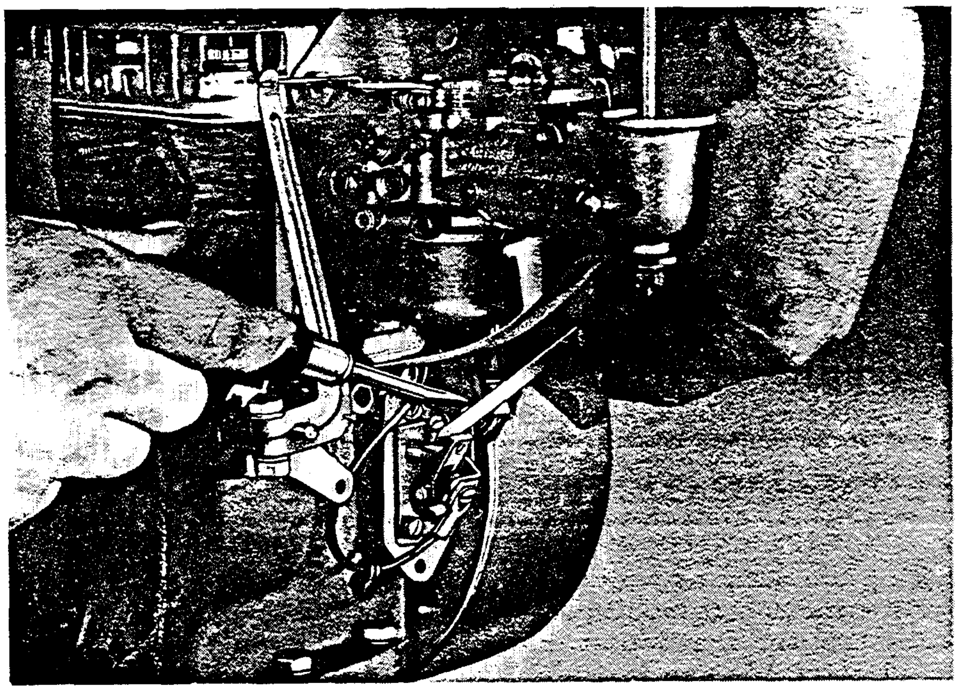


FIGURE 15 - ADJUSTING BREAKER POINT GAP

Timing--Magneto Equipped Engines

All Kohler engines have the timing marks shown on the flywheel so that the breaker points can be manually adjusted to open at precisely the right instant to achieve optimum efficiency and performance. A timing sight hole is usually provided on the flywheel housing.

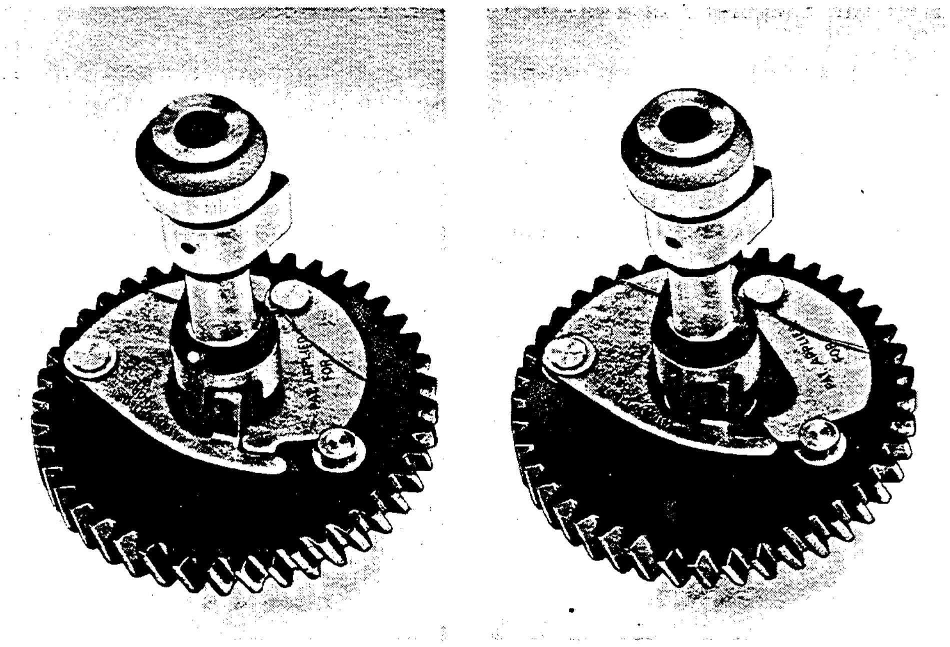
The breaker points on flywheel magneto equipped engines are mounted externally for ease of service and adjustment. This assembly is located within the external type magnetos on engines so equipped.

Since the actual timing procedure varies from model to model, our discussion on timing will have to be on the general side. The procedure as set forth in the service manual for each particular model should be referred to when timing the ignition system.

Timing--ACR Equipped Engines

The Automatic Compression Release system (ACR) now standard equipment on all Kohler single cylinder engines with the exception of the K91, eliminates the need for a complicated spark advance mechanism. On ACR equipped engines, the spark is fixed at the "spark run" setting.

In the foregoing, we mentioned the necessity of a spark retard at starting speeds to avoid the "kickback" caused by the maximum expansion pressures being applied to the piston before it reached TDC. ACR eliminates this kickback by releasing a certain amount of compression while the engine is at the lower starting speeds. The ACR system also offers the distinct advantage of requiring far less cranking effort.



STARTING POSITION RUNNING POSITION

FIGURE 16 - ACR CAMSHAFT

This system consists of two weights which are activated by centrifugal force. One of the weights, called the actuating weight, is designed with a tab which acts as an overlap on the cam and trips the exhaust valve open as the piston is upward on the compression stroke. The other weight locks the actuating weight in position at speeds below 650 RPM. When this speed is exceeded, centrifugal force causes the free end of each of the weights to move outward which unlocks the actuating weight and drops the overlap into a cavity provided for it on the cam. Since the overlap now has no effect on the exhaust valve, all decompression action ceases and the engine operates at full power in the conventional manner. All existing Kohler single cylinder engines, with the exception of the K90 and the K330 series can be converted to the ACR system.

Timing--External Magneto Equipped Engines

As discussed previously, there are two types of external magnetos used on Kohler multi-cylinder engines. The timing procedure, therefore, becomes more complicated and the step by step procedure as set forth in the service manual must be followed.

Generally speaking, the amount of adjustment of the ignition spark of an external magneto is limited to the extent the magneto can be turned in its mounting. Special slots in the flanges usually provide the possibility of advancing or retarding the spark to about 10 degrees. The adjustment is accomplished by loosening the mounting bolts and turning the entire magneto assembly to the desired position. A timing light must be used to check the timing after the magneto is assembled and tightened.

A special type of double end ignition coil is used on the standard K662 engine. The magneto used has no distributor, instead both ends of the secondary winding of the coil are brought out for connection to the two spark plugs. This results in one spark having negative polarity and the other positive polarity on the center electrodes. It also results in a spark being issued every revolution in both cylinders.

Usually a timing window is provided on the distributor type external magneto. A white index line passes this window to indicate that the distributor arm is in line with the high tension socket nearest it. When the socket chosen to fire number one cylinder is indicated in the timing window, the magneto should be inserted into the gear train. Care must be taken that it is actually the number one cylinder that is on the firing stroke when this mark lines up with its index on the timing window.

T I Series No. EN-3

TECHNICAL INFORMATION

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GASEOUS FUELS

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CONTENTS

GASEOUS FUELS

General

The purpose of this manual is to present information on the various gaseous fuels and fuel systems used on Kohler Engines and Electric Plants. The word gaseous describes a natural vapor or gas state. Gasoline, a liquid, is often referred to as "gas", however, in this discussion, gas denotes the gaseous fuels. The fuel types used are:

1. Natural gas
2. Liquified petroleum gas (LPG)
3. Manufactured gas

Some typical gas systems are illustrated. This information is intended only as a guide and should not be used as a final installation blue print due to variation in local and state laws governing storage, handling and use of gaseous fuels. A competent fuel supplier should be aware of these laws.

Natural and LP Gases

Natural and the LP gases are very similar in origin, in fact, they are all of the methane series and are considered natural gases. They are hydrocarbon derivatives of the petroleum industry. Without going too deeply into chemistry, they consist of carbon and hydrogen compounds, each with a different molecular structure. Natural gas is composed of methane and a small percentage of ethane. Referring to Figure 1, we see that methane has the simplest molecular structure, that is, four hydrogen atoms joined to a single carbon atom.

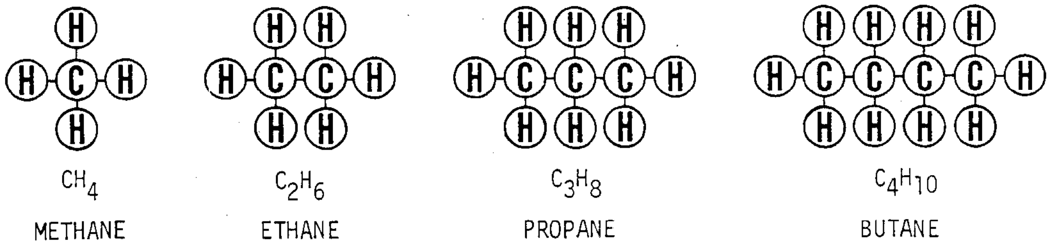


FIGURE 1 - MOLECULAR STRUCTURE OF PETROLEUM GASES

Liquified petroleum gas consists of propane, butane or a mixture of the two gases. Their molecular structures are more complicated than methane or ethane. Butane has a strange property of being able to form two different structures. Iso-butane has the same number of hydrogen and carbon atoms but in a different molecular arrangement. Often both butane and iso-butane are combined in the commercially available butane gas. This is mentioned since the boiling point of fuel containing iso-butane is lower than that of butane.

Petroleum and the associated natural gases are formed as a result of ages of decomposition or decay of organic material. Natural gases are found under pressure in underground rock formations which also contain liquid crude oil. In earlier days, natural gases were considered a nuisance and were flared or burned off before the petroleum was taken from the well. Today, these fuels are as important as the crude oil itself and laws dictate that they are used commercially rather than disposed of as waste products.

Natural gas is usually taken directly at the oil well and piped through a network of transmission lines directly to the user. For this reason, its quality varies according to the field from which it was taken. Natural gas and the LP gases are also produced as by-products of petroleum refining.

Manufactured Gases

Manufactured gas is being widely replaced with natural gas but is still available in some areas. Manufactured gas is made by burning coal and a mixture of air and steam under such conditions that the resulting products are largely carbon monoxide and hydrogen. It also contains a certain degree of nitrogen which was present in the air used in the process. The percentage of nitrogen in the manufactured gas detracts from the quality of the fuel.

Manufactured gas can also include sewage gas obtained in the process of sewage disposal. Sewage gas averages about 70% methane with varying portions of carbon dioxide and hydrogen sulphate. In some areas, manufactured gas is enriched by addition of natural gas.

RATING GAS FUELS

In any discussion of fuels, the boiling point, heating value (BTU) and octane rating are used for comparative purposes.

Boiling Point

This refers to the point at which fuel changes from liquid to vapor state. With gasoline, this transition takes place very slowly. The initial boiling point of gasoline is approximately +97° F. but it is not completely vaporized until the temperature exceeds +400° F. With other gases, this transition takes place almost instantly as the temperature reaches the boiling point. In the accompanying table (No. 1) note that the boiling point of propane is -44° F. while for butane it is +32° F. This particular temperature range makes possible the liquification process of butane and propane and the resulting practical storage of this gas in liquid form.

FUEL COMPARISON CHART

PHYSICAL PROPERTY @ 60° F.	BUTANE	PROPANE	NATURAL GAS	MFGD. OR SEWAGE GAS	GASOLINE	DIESEL FUEL
Normal Atmospheric State	Gas	Gas	Gas	Gas	Liquid	Liquid
Boiling Point (F.)						
Initial	+32°	-44°	-259°		+97°	+350°
End	+32°	-44°	-259°		+420°	+675°
Heating Value BTU's per:						
Gallon (Net - LHV)	94,670	83,340	63,310		116,400	130,300
Gallon (Gross)	102,032	91,547			124,600	139,000
Cubic Foot (Gas)	3264	2516	1000	600-700	6390	
Density Cubic feet of Gas Per Gallon (Liquid)	31.26	36.39	57.75		19.50	
Weight (Lbs.) Per Gallon Liquid	4.81	4.24	2.65		6.16	7.08
Octane Number						
Research	94	110+	110+		82-100	
Motor	90	97			75-90	

Heating Value

Fuels are measured according to heating value which is specified as BTU's per cubic foot or per gallon. A BTU or British Thermal Unit is a standard for the amount of heat required to raise one pound of water one degree Fahrenheit under controlled laboratory conditions.

Some confusion results from the fact that a supplier will often rate a fuel at its high heat or gross value rather than at its low heat value which is the more realistic rating for engine fuels. When hydrocarbon fuels combine with oxygen in the combustion process, a certain amount of the BTU content is wasted in the production of water vapor which is carried away with the exhaust gases. This vapor cannot be avoided since it is the natural chemical reaction to the combination of hydrogen and oxygen. The greater the proportion of hydrogen in a fuel, the greater the power loss. High or gross heat values do not take in account this loss, however, low or net heat values are derived at as useful heat values only. This is brought out, since the difference between high and low heat value may be as great as 10 to 14 per cent. When specifying a fuel, make sure that the supplier is stating BTU content at the low heat or net value rather than at gross value.

Octane Rating

The octane rating of a fuel is specifically a rating of its anti-knock qualities. If a fuel burns too fast or explodes in the combustion chamber of an engine, it produces a violent knock which can damage the engine.

To rate anti-knock qualities, octane, which is one of the liquid hydrocarbons present in gasoline, was arbitrarily selected and its anti-knock qualities assigned a value of 100. Octane is therefore used as a basis or comparison figure in rating anti-knock qualities of fuels. The lower the octane rating, the greater the objectionable knock. The gaseous fuels have better octane ratings than gasoline as we can see in the accompanying comparative data chart. Tetraethyl lead and other compounds are added to gasoline to slow down or smooth out its combustion process and thereby increase its anti-knock ratings.

There are two methods of rating anti-knock qualities. One is the Research method which is basically a low speed laboratory test of the fuel. The other is called the Motor octane rating and is a more realistic rating under conditions normally encountered in high speed engine operation. Octane rating usually is stated as the research number which is often considerably higher than the motor number.

COMPONENTS, GAS FUEL SYSTEMS

Following is a brief description of the more common components in gas fuel systems. Since many of the components are of different manufacture, the illustrations are intended to show the basic function rather than to authentically depict any particular design. In many cases, a component of definite function may have several different names. In these cases, the various names are listed but a single specific or basic name is emphasized. The components are listed noun first, in alphabetical order.

Carburetor - Straight Gas (Suitable for use with gaseous fuels only):

Since a gas carburetor receives fuel in gaseous state, it obviously does not have to provide further vaporization of the fuel. A gas carburetor therefore serves to control the ratio of gas to air under varying load and speed conditions.

There are two basic types of gas carburetors now in general use on Kohler Engines. One carburetor type utilizes the venturi and nozzle system while the other type (Impco) uses a diaphragm which is activated by pressure differential.

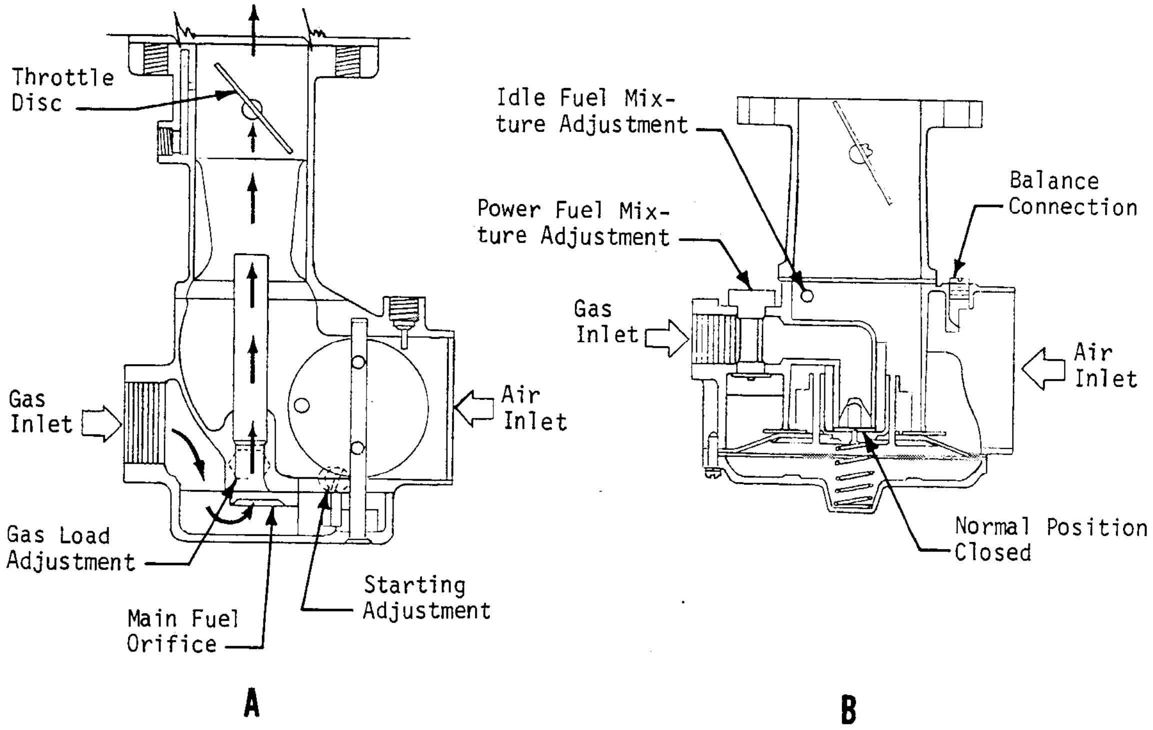


FIGURE 2 - GAS CARBURETOR TYPES - (A) VENTURI (B) DIAPHRAGM

In a venturi type carburetor, the gas nozzle is located at the point of greatest pressure drop inside the venturi. This creates a suction within the nozzle that varies with changing rate of air flow and thus meters a greater volume of gas at heavier loads and a decreased volume at lighter engine load-

The throttle or butterfly valve regulates the rate of air flow through a carburetor. When the engine is at top speed, this valve is wide open and offers little restriction to air flow. Closing the throttle causes a decrease in air flow and lowers engine speed and power. As the valve closes, pressure builds up behind the valve which reduces pressure through the venturi and past the fuel nozzle. The ratio of air to fuel is thus kept fairly constant at varying speeds.

The diaphragm type uses a diaphragm activated air-gas valve to proportion the flow of air and gas. A metering valve is linked to the diaphragm, therefore the greater the air flow, the greater the valve opening and with a corresponding increase in intake of gas. Since the valve is open only by vacuum created by passage of air, it closes completely when the engine is stopped.

Carburetor - Gas-Gasoline:

In some applications, it is desirous to have gas as the main fuel source but with a provision for operation on an independent fuel supply such as gasoline for emergency operation when the gaseous fuel is not available.

Such a fuel system can include a carburetor that is designed specifically for both fuel types or a standard gasoline carburetor used with a gas adapter or spud-in device.

The gas-gasoline or so called combination carburetor utilizes the same principle of operation as the previously discussed venturi-nozzle type gas carburetor. In addition, the combination carburetor contains a float chamber and calibrated passages and orifices for precision metering of the liquid fuel. Gasoline is introduced into the air stream by a jet located in appropriate position in the venturi. The change-over from gas to gasoline is accomplished by opening a gasoline shut-off valve and immediately afterward shutting off the gas fuel supply. When changing back to gas operation, the engine should be allowed to run momentarily after the gasoline valve has been closed. It is allowed to run only until it starts to misfire then the gas valve is opened. If this is not done, the presence of both gas and gasoline while the float tank is draining, may result in an over-rich mixture of the fuel.

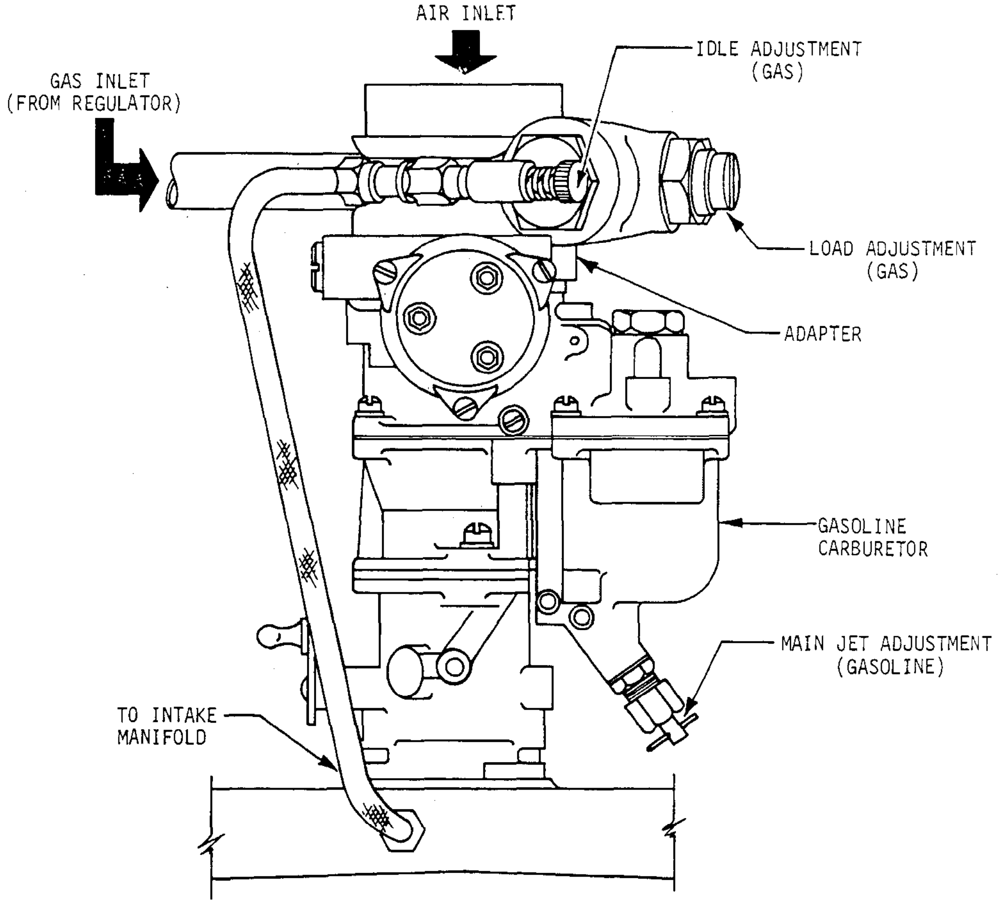


FIGURE 3 - GASOLINE CARBURETOR WITH GAS ADAPTER

An engine equipped with a gasoline carburetor can be modified to also use a gaseous fuel by addition of a gas adapter and of course, the other necessary gas regulating equipment. The adapter is installed between the carburetor and the air cleaner. On this type, the adapter consists of a gas jet and venturi. Accurate metering of the gas is accomplished by load and starting or idle adjustment screws in the body of the adapter.

The Impco gas mixer, which is now used on many electric plants, can also be classified as a type of adapter. It utilizes a diaphragm operated air-gas valve rather than a venturi. The mixer is also installed between the gasoline carburetor and the air cleaner. Load adjustment is made at the mixer.

"Spud-in" devices are also used on combination gas-gasoline systems. One type is simply a gas nozzle which is fitted into a hole drilled in proper position in a standard gasoline carburetor so that gas is injected into the venturi. On this type only the gas load can be adjusted. A more elaborate Spud-in consists of an adjustable nozzle and gas valve arrangement. Moving the nozzle further into or out of the venturi alters the amount of air induced. The other adjustment on the gas valve, as shown in Figure 4, controls the volume of gas.

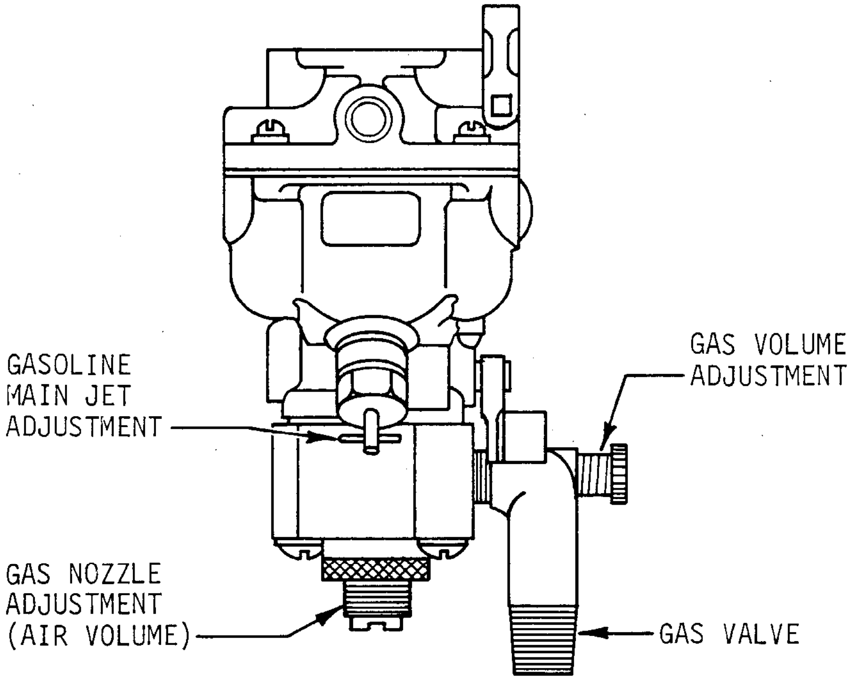


FIGURE 4 - GASOLINE CARBURETOR WITH GAS SPUD-IN

Converter (See Vaporizer)

Cylinder (See LPG Tanks)

Economizer:

Certain straight gas carburetor models are equipped with a device which leans out the fuel mixture at part throttle operation. When an engine is warm and operating at normal speeds, fuel is supplied to the venturi through main fuel orifices in the carburetor. The economizer functions to vary the mixture ratio according to changing load demands. For example, when an engine is operating at normal speeds with light load, the manifold vacuum will be high. The economizer is activated by changing vacuum values to restrict the metering orifices at high vacuum and thereby lean out the fuel. As engine load is increased, the corresponding drop in vacuum is sensed in the economizer which then reduces the orifice restriction, and allows a richer fuel mixture.

Filter - Dry Gas:

This is used in the fuel line when gas is supplied in vapor state. It functions as a filter to trap any solid impurities that may be present in the fuel. The type commonly used has a felt or wool element which will trap solid particles of .0001 and larger.

Filter - Wet Gas:

The use of this type is restricted to LPG systems where the fuel is transmitted in liquid form from the source to a vaporizer. Its design and function is very similar to the common gasoline fuel filter except that it is constructed to withstand the high pressures encountered in LPG liquid withdrawal systems. It has a serviceable element and sediment bowl and should be serviced periodically.

Filter - Lock (See Electric Fuel Valve)

Gauge - Ounce Pressure:

This gauge is mentioned for, even though it is usually not a permanent component of a fuel system, it is very useful in checking the regulated inlet and outlet pressures which are rated in ounce per square inch values. Since most ounce pressure gauges are completely sealed units, they can be permanently inserted in a gaseous fuel system. Most regulators and carburetors have provisions for inserting these gauges, either as permanent or temporary fixtures.

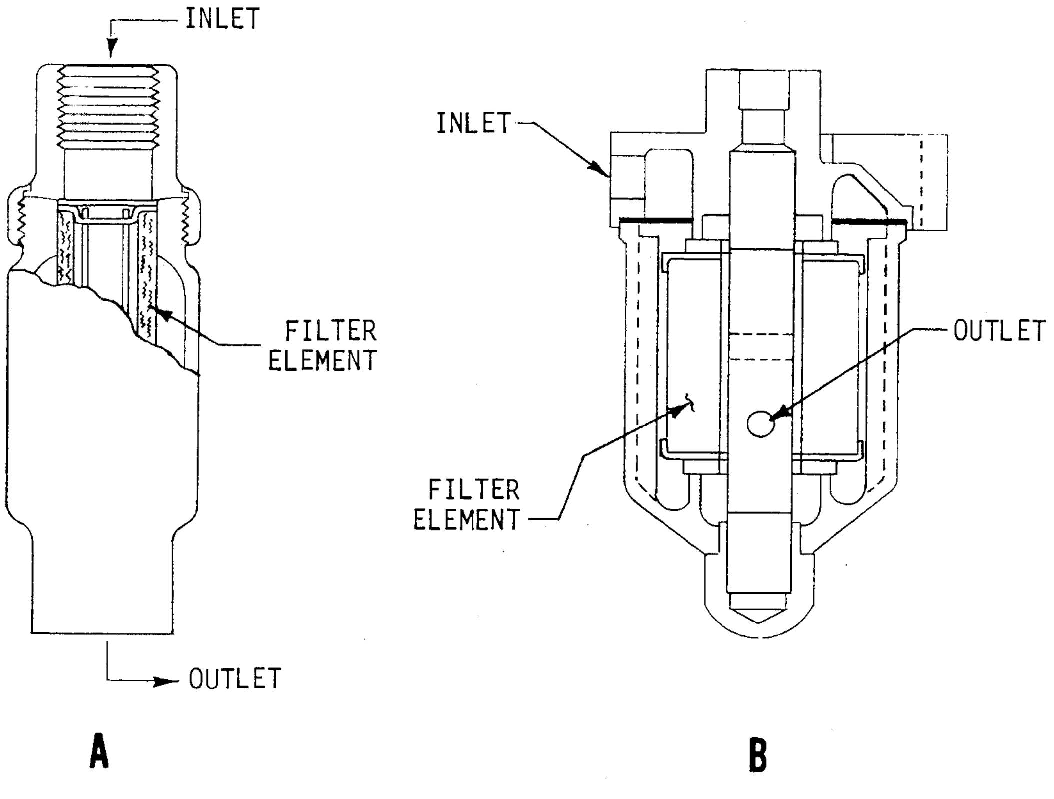


FIGURE 5 - GAS FILTER TYPES - (A) DRY GAS (B) WET GAS

Line - Idle:

At idle speeds, the velocity of air through a carburetor may not be sufficient to draw enough fuel to sustain engine operation. For this reason, many carburetors incorporate a separate idle fuel system. The idle line carries fuel from the secondary regulator to the air intake side of the carburetor where fuel is introduced at the lower idle speeds. When the fuel demand drops to a certain point, the regulator diverts fuel from the main fuel system into the idle fuel system. This is explained further under our discussion on "Regulators". On systems having the idle line, the idle mixture adjustment is made at the regulator, rather than at the carburetor. On larger plants, the use of an idle line is often unnecessary since the engines are very seldom run at the lower idle speeds.

Line - Balance:

The problem of an over-rich fuel mixture which can be caused by restricted air cleaner is eliminated by connecting the atmospheric side of the secondary regulator to the carburetor air horn. This balance ensures a constant ratio of fuel to air under varying degree of air cleaner restriction. Use of the balance line is restricted to the larger engine applications where the air requirements and ratio are more exacting.

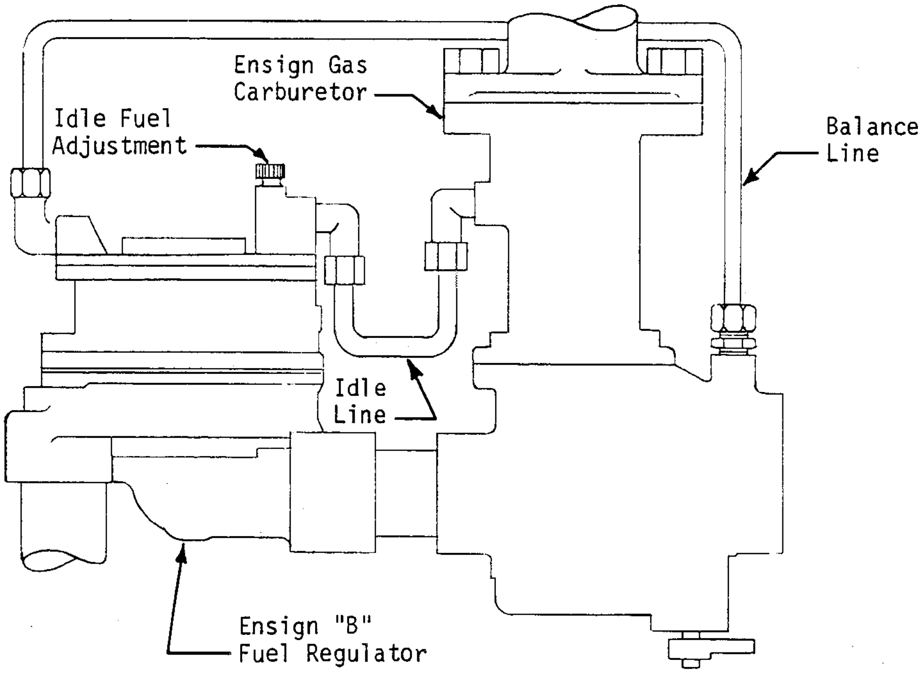
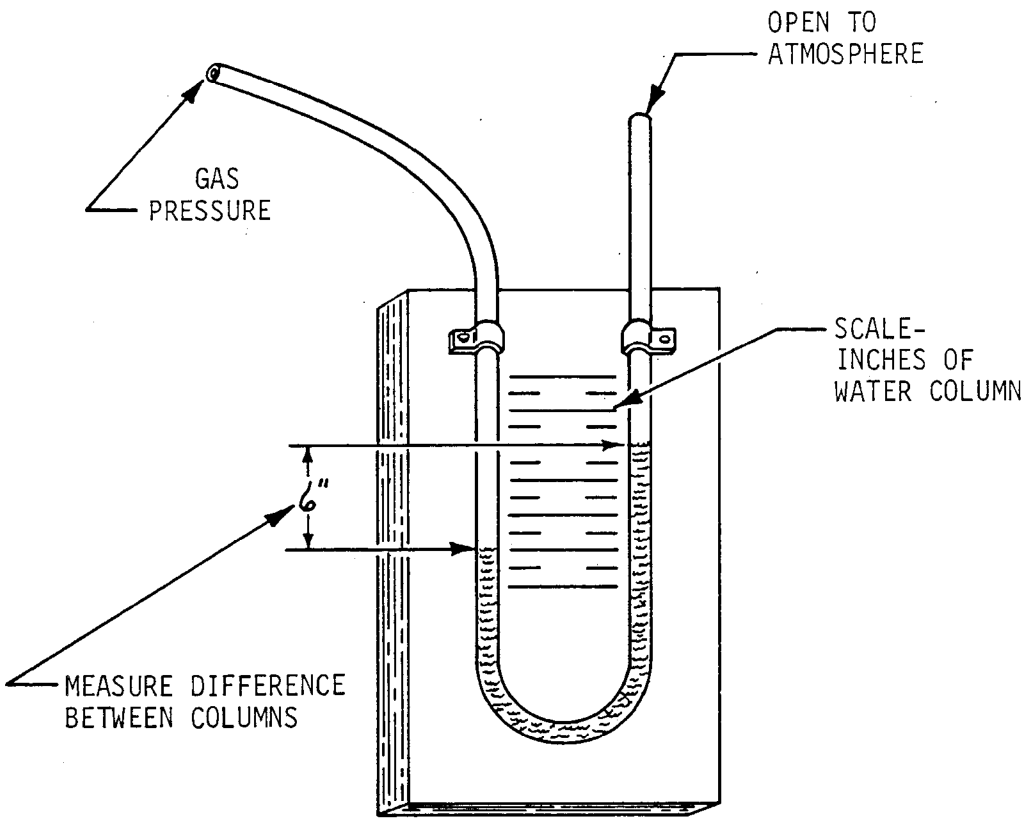


FIGURE 6 - IDLE AND BALANCE LINE HOOK-UP



1 INCH WATER COLUMN = .6 (Approx.)
OUNCE PER SQUARE INCH PRESSURE

FIGURE 7 - TYPICAL "U" TUBE MANOMETER

Manometer, "U Tube":

Often the pressure of natural gas will be rated in inches of water column. Natural gas is supplied under moderate pressures which are normally between 7 and 11 inches of water column or 4 to 6 ounces per square inch. For this reason, it is seldom necessary to check line pressures except in cases where too low pressure is suspected.

The manometer is not a permanent fixture in a fuel system, but it is a simple and convenient tool for measuring inlet pressures to the secondary regulator. A manometer consists of a clear glass tube bent in the shape of a "U". One end of the tube is open to atmosphere while the other is connected to the gas line. The gas pressure acts on a column of water in the tube and is read in inches which are calibrated on the manometer. One inch of water column equals approximately .6 ounces per square inch.

Piping, Gaseous Fuels:

Before undertaking installation of piping from a remote fuel source to an engine, a check should be made concerning local and state laws governing use of gas fuels. If none exists, the regulations and standards set forth by the National Fire Protection Association (NFPA) should be followed for safe and proper installation. These regulations are covered in the following NFPA publications:

No. 37 - Combustion Engines
No. 54 - Gas Appliances and Piping
No. 58 - Storage and Handling LPG

These are available at nominal price from:

The National Fire Protection Association
60 Battery March Street
Boston, Massachusetts 02110

For the purpose of calculating piping size, the fuel consumption of an engine is figured at approximately 10,000 BTU's per horsepower per hour. Thus, a 10 HP engine will require 100,000 BTU's per hour. Operating on 1,000 BTU natural gas, this engine would need 100 cubic feet of gas per hour. In addition to fuel consumption, the following factors must be considered:

1. Pressure loss due to number of fittings.
2. Specific gravity of gas.
3. Pressure loss due to length of piping.

The accompanying Gas Flow Chart lists the capacity of various sizes and lengths of pipes. The capacity, which is given in cubic feet per hour, is calculated using the specific gravity of air (1.0) as the base. To calculate maximum flow of any particular gas, we must multiply the capacity stated by the multiplier listed next to the specific gravity of the gas involved. The local fuel supplier will usually state the actual specific gravity for the fuel to be supplied. A pressure drop of 0.3" (water column) is used to account for a nominal number of fittings and metering equipment in this table. A different loss may be encountered. For this reason, several different loss values are stated along with corresponding multipliers.

Referring to the fuel consumption figures, we can use this chart to calculate proper pipe sizing. If the engine is located, for example, 30 feet from the main source, a pipe size of 3/4 inch would be needed to deliver the 100 cubic feet of natural gas per hour.

PIPE SIZE - GAS FLOW CHART

Pipe capacity in cubic feet per hour. Chart based on specific gravity of air=1.0 and a pressure drop of 0.3" (water column). Allowance made for nominal number of fittings. For fuels with differing specific gravity or for different pressure drop, use the multipliers listed below.

LENGTH OF PIPE FT.	IRON PIPE SIZE										
	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"	4"	6"	8"
15	76	172	345	750	1220	2480	3850	6500	13880	38700	79000
30	52	120	241	535	850	1780	2750	4700	9700	27370	55850
45	43	99	199	435	700	1475	2300	3900	7900	23350	45600
60	38	86	173	380	610	1290	2000	3450	6800	19330	39500
75		77	155	345	545	1120	1750	3000	6000	17310	35300
90		70	141	310	490	1000	1560	2700	5500	15800	32250
105		65	131	285	450	920	1430	2450	5100	14620	29850
120			120	270	420	860	1340	2300	4800	13680	27920
150			109	242	380	780	1220	2090	4350	12240	25000
180			100	225	350	720	1120	1950	4000	11160	22800
210			92	205	320	660	1030	1780	3700	10330	21100
240				190	300	620	970	1680	3490	9600	19740
270				178	285	580	910	1580	3250	9000	18610
300				170	270	545	860	1490	3000	8500	17660
450				140	226	450	710	1230	2500	7000	14420
600				119	192	390	600	1030	2130	6000	12480

SPECIFIC GRAVITY	MULT.	SPECIFIC GRAVITY	MULT.	PRESSURE DROP	MULT.
.50	1.10	1.0	.775	0.1	.577
.55 Sewage gas	1.04	1.2	.707	0.2	.815
.60	1.00	1.4	.655	0.3	1.000
.65 Natural gas	.962	1.5 Propane	.633	0.5	1.29
.70	.926	1.7	.594	1.0	1.83
.80	.867	1.9	.565	2.0	2.58
.90	.817	2.1 Butane	.535	5.0	4.08

ACTUAL DIMENSIONS (INCHES)	NOMINAL PIPE SIZE, INCHES							
	1/4	3/8	1/2	3/4	1	1-1/4	1-1/2	2
INSIDE DIAMETER	0.364	0.493	0.622	0.824	1.049	1.380	1.610	2.067
OUTSIDE DIAMETER	0.540	0.675	0.840	1.050	1.315	1.660	1.900	2.375

Regulator - Primary:

The function of the primary, or as it is often called, the field regulator, is to provide initial control of fuel under pressure as it comes off a transmission line, or in the case of LPG, from a storage tank.

A natural gas supplier may boost pressure somewhat to achieve even distribution, however, these line pressures are usually under 50 psi. For this reason, the primary regulator used with a natural gas system does not have to regulate the high inlet pressures commonly associated with LP gas systems. A primary regulator steps down line pressures to more workable outlet values ranging from 4 to 6 ounces per square inch.

One type of regulator used with LPG fuel is actually a regulator and vaporizer in one unit. The regulator functions in the same general way. Refer to the following data on vaporizer for operating principles of the vaporizer system.

Another type of regulator used especially on the smaller engines, is the two stage regulator. This, as the name implies, serves as both a primary and a secondary regulator. Its principle of operation is similar to those previously discussed.

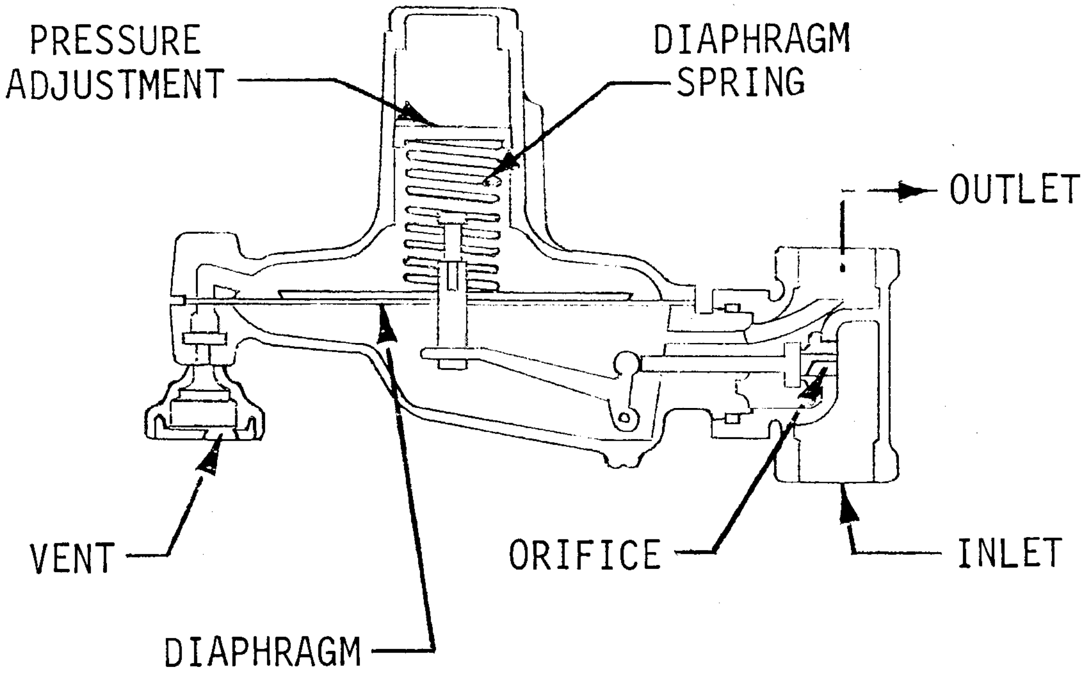


FIGURE 8 - TYPICAL PRIMARY REGULATOR (HIGH PRESSURE)

Regulator, Secondary:

This regulator provides the final control of gas prior to its entering the carburetor. This is also called the low pressure regulator.

The secondary regulator receives gas at a pressure of 4 to 6 ounces from the primary regulator. It reduces this pressure to about 3 ounces or according to the engine needs. A typical regulator, as shown in Figure 9, operates as follows: Suction from the carburetor is applied to the regulator at the gas outlet and is communicated by way of the suction passage to the lower side of the upper diaphragm. As this suction pulls the diaphragm down, its push rod opens the pilot valve. The reduced pressure passes through pilot valve into the area of the lower diaphragm which creates a pressure differential and lifts the diaphragm and its connecting main fuel valve. This valve in turn allows gas to flow to the carburetor in the quantity according to engine demand.

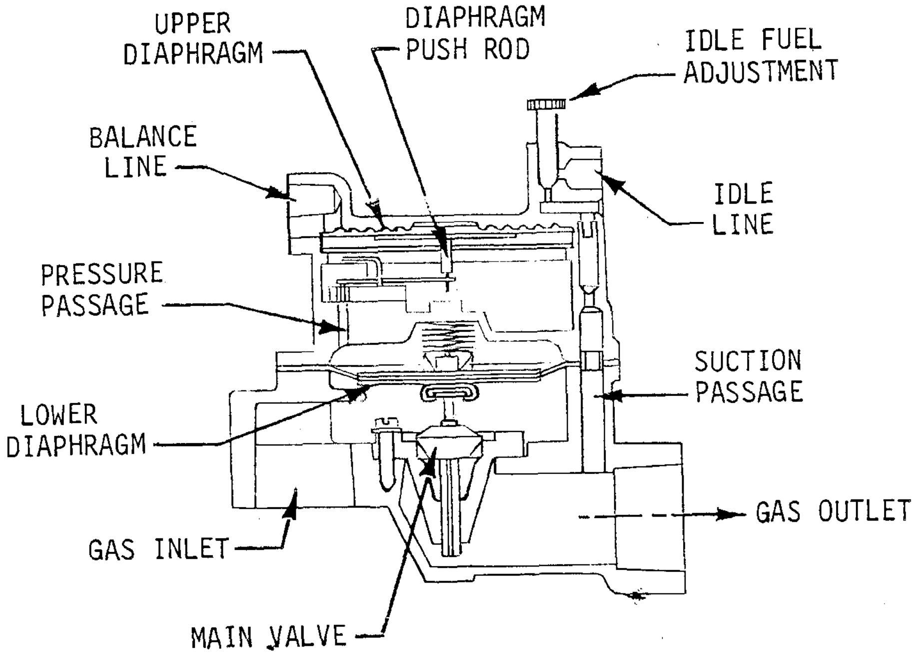


FIGURE 9 - TYPICAL SECONDARY REGULATOR (LOW PRESSURE)

Tanks - LPG Cylinder:

The fuel vessel type is usually the responsibility of the fuel supplier, however, the engine user must be assured of an adequate supply and he must also make certain that the tank or cylinder meets all requirements set forth by local and state laws.

The type commonly used on the smaller stationary installation is a simple cylinder usually equipped only with a manual shut off valve. Although this type is of adequate strength to withstand the highest tank pressures, it has a drawback in that the outlet valve is unprotected against damaging blows which could present a hazard if damage is sufficient to part the valve from the cylinder.

The Interstate Commerce Commission has established certain requirements for construction of tanks used in mobile applications. ICC tanks are common in 20 gallon sizes (100#). On these the valves are protected and they have safety relief valves in case of build up of excessive pressures. The ICC also sets forth requirements for securing these tanks to the vehicle.

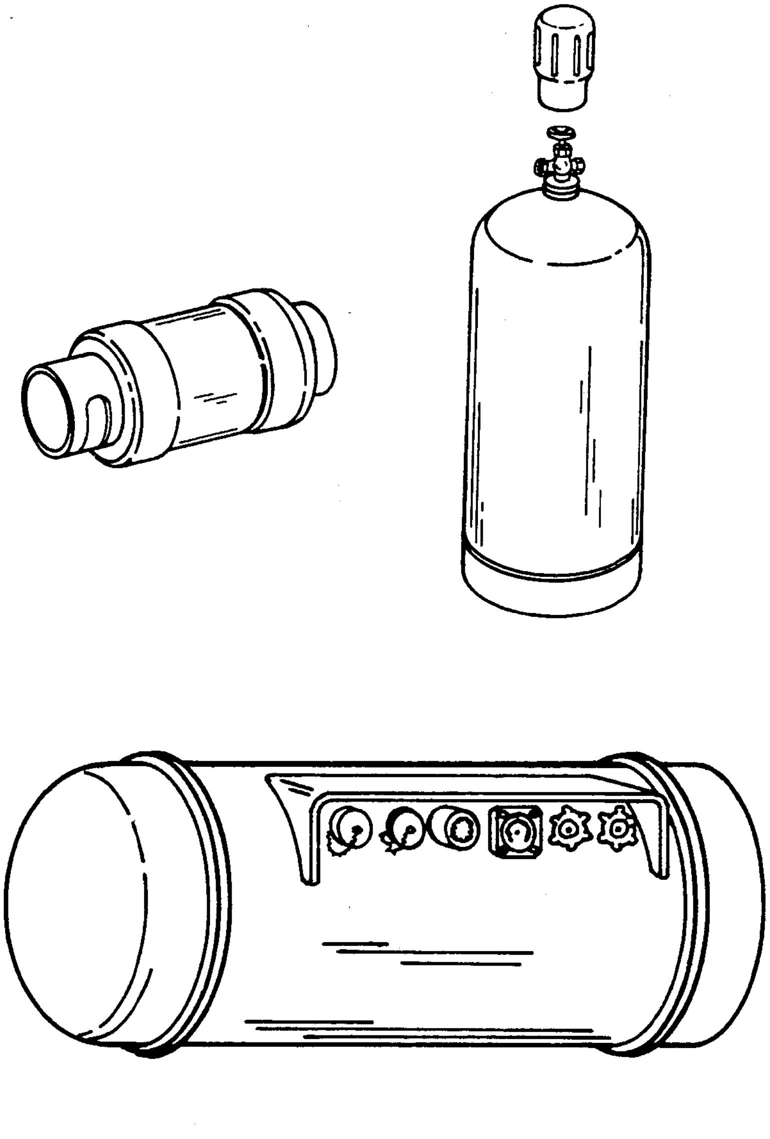


FIGURE 10 - LPG FUEL TANK TYPES

Tanks - LPG Bulk:

The American Society of Mechanical Engineers (ASME) has established design standards for construction of LPG bulk tanks. These range in size from 200 gallon (liquid) capacity all the way up to 90,000 gallons in increments of 25 gallons. Although some of the smaller size tanks are used in mobile applications, the ASME approved tank is generally used in stationary applications. The capacity of fuel tanks used in over the highway vehicle applications are limited to 200 pounds capacity in passenger vehicles and 300 pounds in other vehicles.

Because tank pressures range from 0 to 200 psi in liquid LPG tanks, these tanks cannot be filled to capacity. ASME tanks are equipped with 90 per cent full valves to allow room for expansion of the gases with increase in temperature.

The recommendations of the local fuel supplier should be followed when installing storage vessels and fuel piping.

Valve - Fuel Shut-Off (Manual):

In addition to manifold vacuum or electrically operated safety shut-off valves, an LPG system should include a manually operated fuel shut-off valve located close to the fuel source. A manual shut-off valve is often required by existing regulations in many localities.

Valve - Fuel Shut-Off (Electric Solenoid):

While the regulators used in a gaseous fuel system are designed to close and stop fuel the instant an engine stops, they should not be relied upon to completely seal the fuel system. A ruptured diaphragm or a piece of grit could prevent the valves from seating with a result that gas would continue flowing through the carburetor into the engine and out into the surrounding air. Since gaseous fuels are heavier than air, they tend to settle in low areas which could present a serious hazard--especially in enclosed applications.

Most automatic fuel shut-off valves use electrically activated solenoids that seal off the fuel the instant the ignition switch is turned off. Many solenoid fuel valves also have a timing device that will shut off fuel in the event that the engine stalls with the ignition on.

On the small to medium sized plants using LPG liquid withdrawal systems, a combination fuel shut-off and wet gas filter unit is often used. This is often referred to as a filterlock.

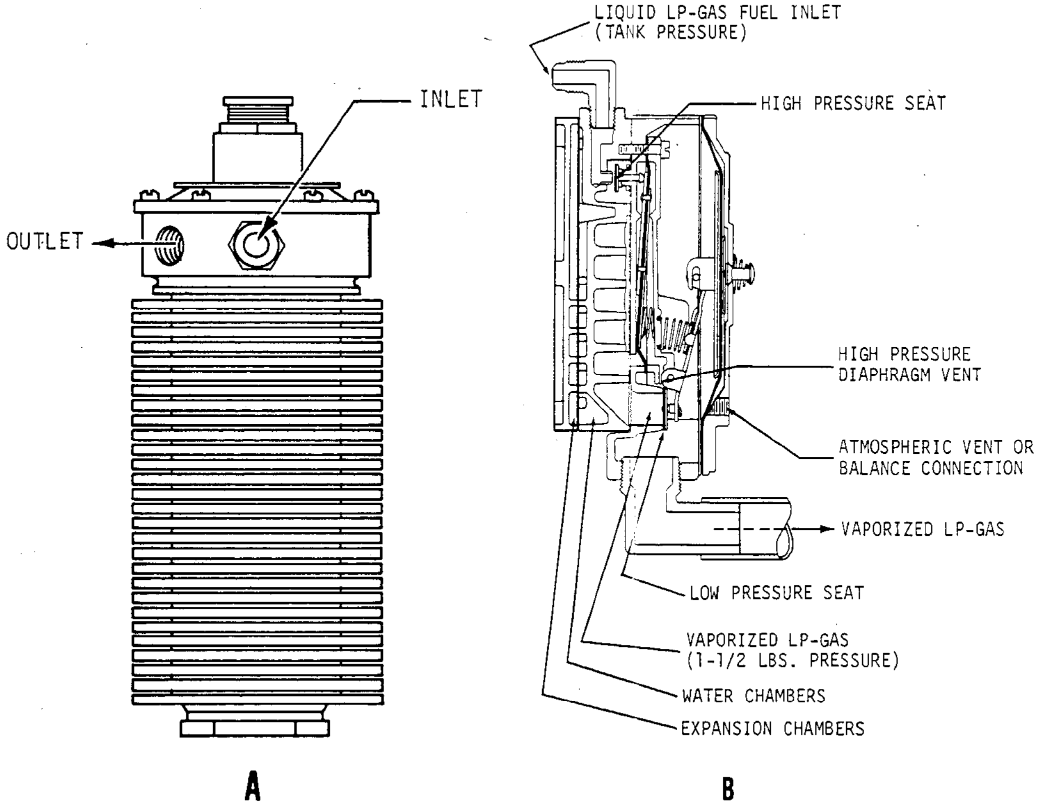


FIGURE 11 - TYPICAL VAPORIZERS - (A) AIR COOLED ENGINES
(B) VAPORIZER - REGULATOR FOR LIQUID COOLED ENGINES

Vaporizers:

Vaporizers are devices used exclusively with LPG systems. LPG in liquid form is introduced under tank pressure into the vaporizer which uses heat to convert the liquid into vapor state. Vaporizers are often referred to as convertors - both names describe its function. There are several types of vaporizers. The type shown in Figure 11 (A) is strictly a vaporizer and must be used in conjunction with other pressure regulators. The types classified as vaporizer-regulators in Figure 11 (B) provide vaporization plus primary or secondary regulation of gas pressure.

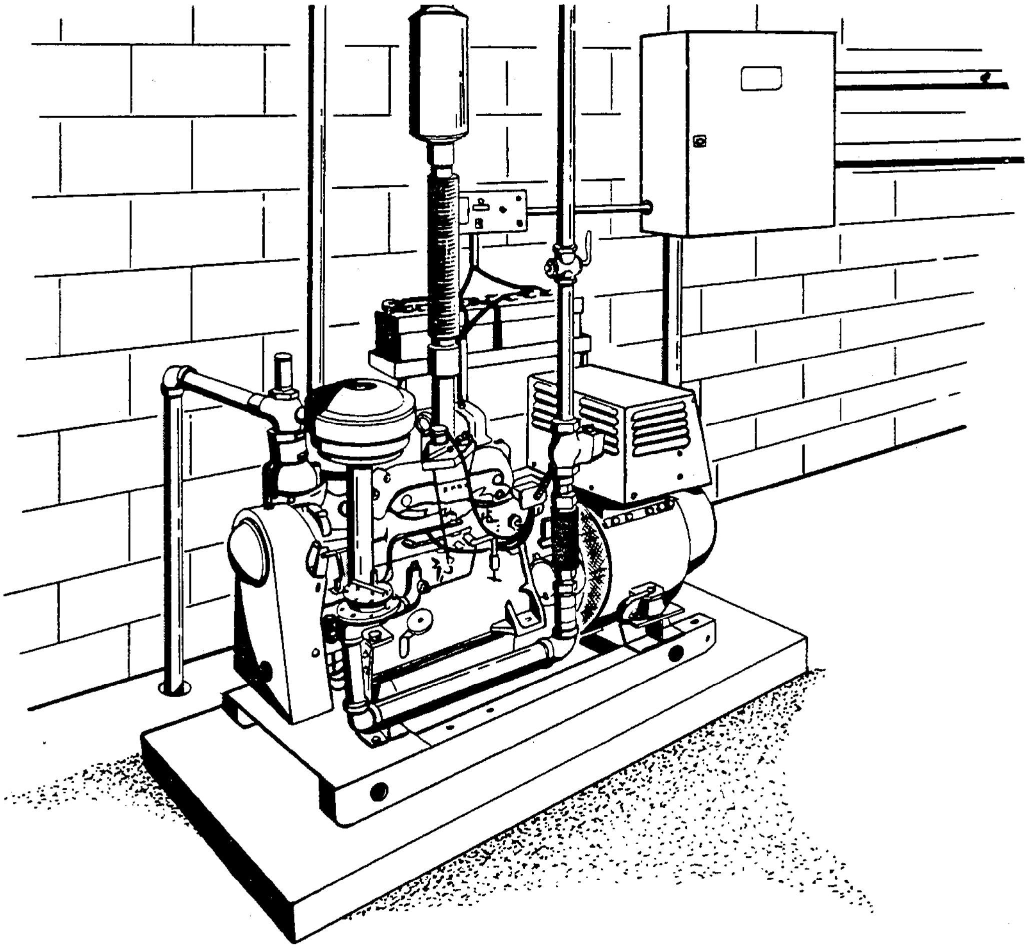
GAS FUEL SYSTEMS

Gaseous Fuel Systems - General

Ensign and Impco gas fuel systems are in general use on Kohler Electric Plants. They operate on a slightly different principle and at different gas pressures.

The Ensign systems utilize the venturi and nozzle type carburetor. Passage of air through the venturi creates a suction in the nozzle which is transmitted back to the secondary regulator. The regulator, in turn, meters fuel to the carburetor according to the amount of negative pressure created within the nozzle. Fuel is metered to the carburetor at atmospheric pressure.

On the Impco natural gas system, fuel is supplied to the carburetor at a positive pressure of approximately 3 ounces per square inch at idle. On the LP gas systems, fuel is introduced at a negative pressure of approximately one inch water column or .6 ounces per square inch. Since mixture is controlled by pressure in the Impco system, higher pressure is necessary for the lower BTU fuels.



The gaseous fuel systems used can be grouped in four general classifications. The fuel systems are discussed in the following sequence:

1. Liquified Petroleum Gas (only)
2. Natural Gas (including manufactured gas)
3. Dual Fuel Systems (natural and LP gas)
4. Combination Gas-Gasoline

In operation of a gasoline fueled engine, the intake manifold will contain air, gasoline vapor and a percentage of mist and liquid gasoline which not only contributes to incomplete combustion but washes down cylinder walls and thereby dilutes lubricating oils. Since gas is in vapor state when induced in an engine, it follows that more complete combustion and no significant oil dilution will occur. Also if incomplete combustion occurs due to improper carburetion, the unburned fuel, being in a vapor state, will be exhausted along with the other combustion gases.

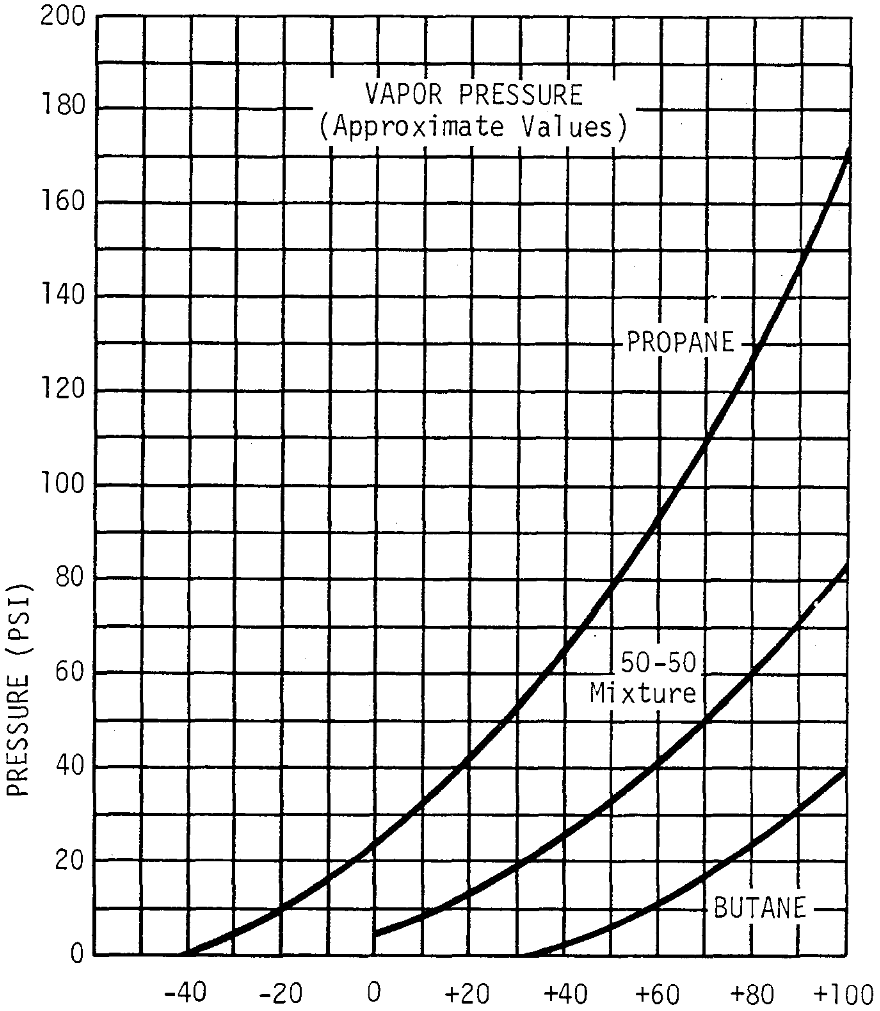
Based on the foregoing, it would seem obvious, due to the lack of dilution, that the oil drain periods can be greatly extended as claimed by many of the gas manufacturers. Some lubrication experts dispute this and contend that while dilution tends to decrease oil viscosity, the opposite is true when no dilution is encountered. This is explained by the fact that as the crankcase lubricant contacts hot engine parts, the lighter "ends" of the oil evaporate which results in an increase in viscosity. Continued operation for extended periods over the hours recommended for oil change would therefore result in operating with oils higher in viscosity than recommended for the engine. Some operators counteract this effect by using oil of one SAE grade lighter when adding between oil changes. For example, SAE 30 used at changes would call for SAE 20 for additions.

Top oilers are recommended on engines using gaseous fuels. While liquid fuels provide a certain amount of lubrication to the valves when induced into the combustion chamber, the "dry" gaseous fuels provide little, if any, lubrication in this area. Therefore, excessive valve wear may be experienced with the gaseous fuels unless some method is used to provide added valve lubrication. A top oiler entrains a fine mist of upper cylinder lubricant in the fuel as it flows through the carburetor and into the combustion chamber.

LP GAS SYSTEMS

The use of LPG as an engine fuel offers several distinct advantages. Since LPG as supplied as a liquid in pressure tanks, it is easily adaptable to mobile applications and also to stationary application where complete independence of an outside fuel supply is required. Furthermore, since LPG does not deteriorate in long periods of storage as gasoline is known to do, a large supply of fuel can be kept on hand indefinitely for extended operation for emergency conditions.

While propane tends to maintain some vaporizing pressure even down to temperatures of -20° F., butane returns to liquid state when the temperature drops below freezing or below +32° F. For this reason, fuel suppliers will usually supply a fuel of higher butane content in hot weather and alter to a higher proportion of propane for cold weather operation. The accompanying chart shows the approximate vapor pressures of the two fuels at varying temperatures.



TEMPERATURE (°FAHRENHEIT)

VAPOR PRESSURE CHART

The ratio of butane to propane is especially important where a large outdoor tank is used in an emergency or stand-by application. For example, a fuel supplier may fill the tank in the warm summer months with a mixture composed mainly of butane, however, this mixture may not offer sufficient vaporization pressure at extremely cold temperatures to start and operate the engine. In these cases, the user should specify the exact mixture which would facilitate operation under all temperature conditions.

Since LPG is supplied in pressurized tanks in liquid form, it must be converted to vapor state before being introduced into the carburetor. The two basic types of LPG systems are classified: Vapor Withdrawal and Liquid Withdrawal Systems.

Vapor Withdrawal Systems

As mentioned earlier, the liquid level in LPG tanks must not exceed 90% of the tank capacity. Generally 10 to 20 per cent of capacity is allowed for expansion of the gas from liquid to vapor state. A vapor withdrawal system utilizes vapor forming in the space above the liquid. This system has a limitation in that the ambient temperature of the air surrounding the fuel tank must be high enough to sustain adequate vaporization of the liquid fuel. In the colder climates, an independent heat source may be necessary to supplement natural vaporization within the tank.

Referring to the LPG vapor pressure chart, we see that straight butane gas has, for all practical purposes, little or no vaporization pressure when the temperature drops below +40° F. Even at +70° F., the pressure is only approximately 18 psi. Some primary regulators will not operate if tank pressure drops below +30 psi while others operate at incoming pressures down to 3-1/2 to 5 psi. Obviously, the fuel mixture and its vaporization pressure at the anticipated temperatures influences the selection of regulatory equipment.

The components of the vapor withdrawal system used in a typical stationary application are as follows:

1. Tank - Adequate capacity to provide vaporization at lowest anticipated temperatures.

2. Piping - Adequate size to provide sufficient volume of gas.

3. Dry Gas Filter - Traps pipe scale and other impurities.

4. Primary Regulator - Reduces incoming tank pressures to 4 - 6 ounces.

5. Fuel Shut-off Valve (Electric Solenoid) - Provides positive shut-off when engine stopped.

6. Secondary Regulator - Senses engine need for fuel and meters proper amount.

7. Carburetor - Straight gas type with or without idle and balance lines to primary regulator. This depends on the particular application.

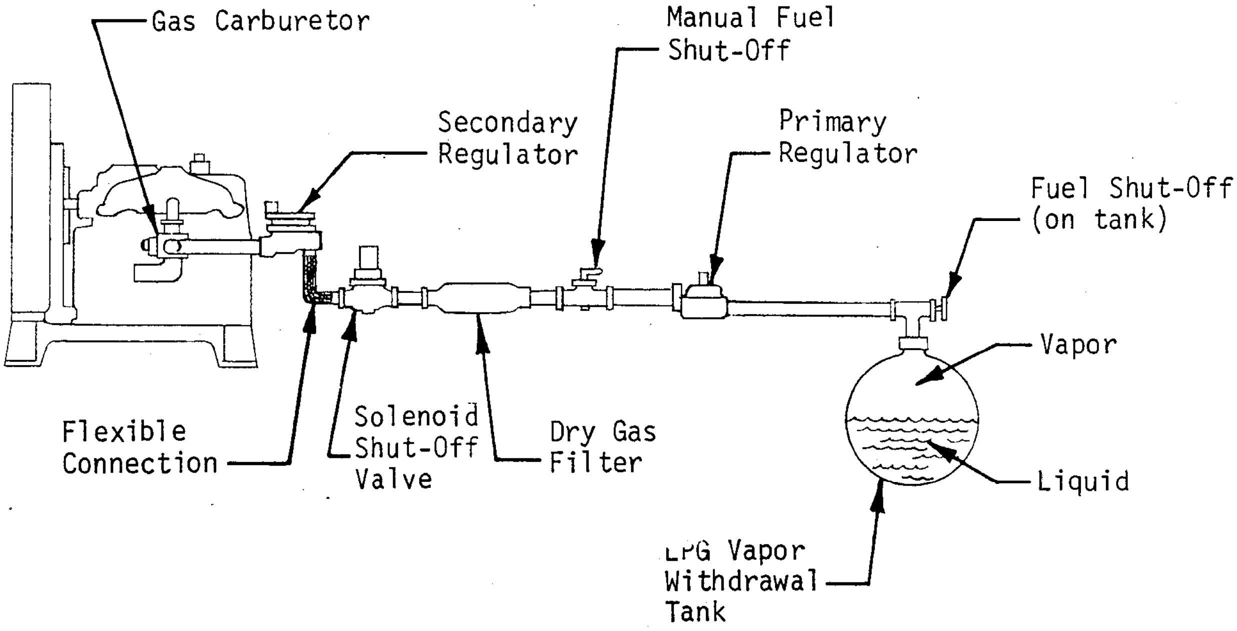


FIGURE 12 - SCHEMATIC OF A TYPICAL LPG VAPOR WITHDRAWAL SYSTEM (ENSIGN)

On mobile applications, the space allowed for the fuel system is usually quite limited. Therefore, the tank capacity is often small and components serving two or more functions are often used. The components of a typical Ensign vapor withdrawal system for mobile applications are as follows:

1. Tank - I. C. C. approved secured by brackets designed to withstand stresses in any direction equal to four times the liquid capacity of the tank. (N. F. P. A. Regulation)

2. Tubing - Since length is usually quite short, pressure approved copper tubing of adequate size can often be used.

3. Two-Stage Regulator - This serves as both the primary and secondary regulator and also can include a lock-off device which shuts off fuel when the ignition switch is turned off. Since the idle adjustment is provided in this regulator, an idle line must be run to the carburetor.

4. Carburetor - Straight Gas

Liquid Withdrawal Systems

If vapor of sufficient quantity is not available in the LPG tank, a liquid withdrawal system must be used. In these systems, LPG in liquid form is directed under pressure from the tank to a vaporizer. On air cooled engines, the vaporizer can be mounted so that it absorbs heat from the engine cooling system. On water cooled engines, coolant is routed through the vaporizer. The components of a typical Ensign high pressure liquid withdrawal system are:

1. Tank - This is specifically designed for liquid withdrawal.
2. Piping - Sufficient size to provide adequate volume of fuel.
3. Manual Shut-Off Valve
4. Wet Gas Filter - Strains impurities from liquid LPG.
5. Vaporizer - Functions as a heat exchanger to convert liquid to vapor state.
6. Two-Stage Regulator - Provides primary and secondary regulation in addition serves to lock off fuel when ignition is turned off. Depending on the application, balance and/or idle lines may be used.
7. Carburetor - Straight gas, with or without economizer.

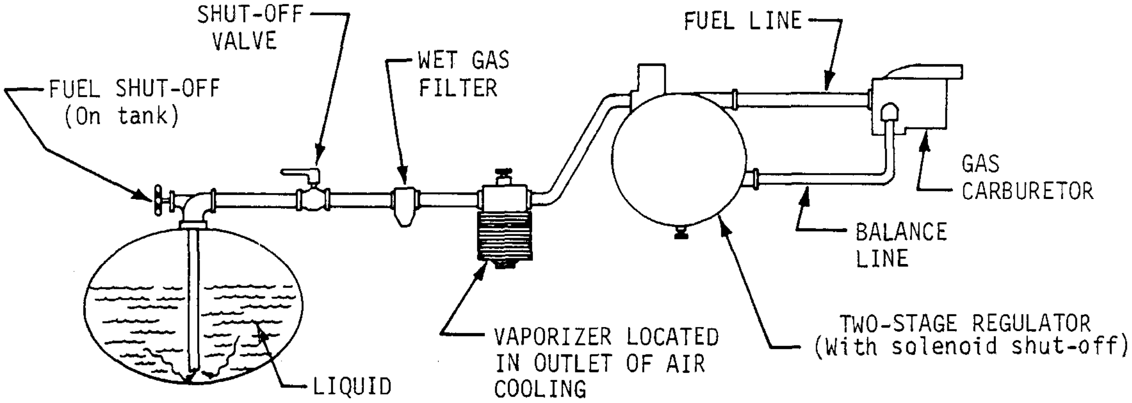


FIGURE 13 - TYPICAL LPG HIGH PRESSURE LIQUID WITHDRAWAL SYSTEM

Another form of high pressure liquid withdrawal system is the Impco system. This system uses a 2-stage vaporizer regulator. Fuel enters the regulator at tank pressure and is reduced to 1-1/2 pounds within the vaporizing chamber. After vaporization, gas passes through a secondary or low pressure chamber where it is drawn off through the outlet to the carburetor.

Fire regulations in certain localities prohibit high pressure fuel lines inside a building or enclosure. This automatically preculdes high pressure equipment on or near an engine installed inside a building. Permissible pressure is usually about 20 PSI.

On water cooled engines the coolant lines can be extended and the vaporizer or vaporizer-regulator mounted outside a structure in areas where freezing temperatures are not encountered (water directed to the vaporizer could freeze). Obviously this can not be done with an air-cooled engine unless an independent heat source is used for vaporization. With the vaporizer mounted outside, high pressure liquid gas is present only from tank to the vaporizer and vaporized gas at permissible pressure is allowed inside the building. The vaporizer must be mounted below the level of the engine water pump and within 25 feet of the engine on these installations.

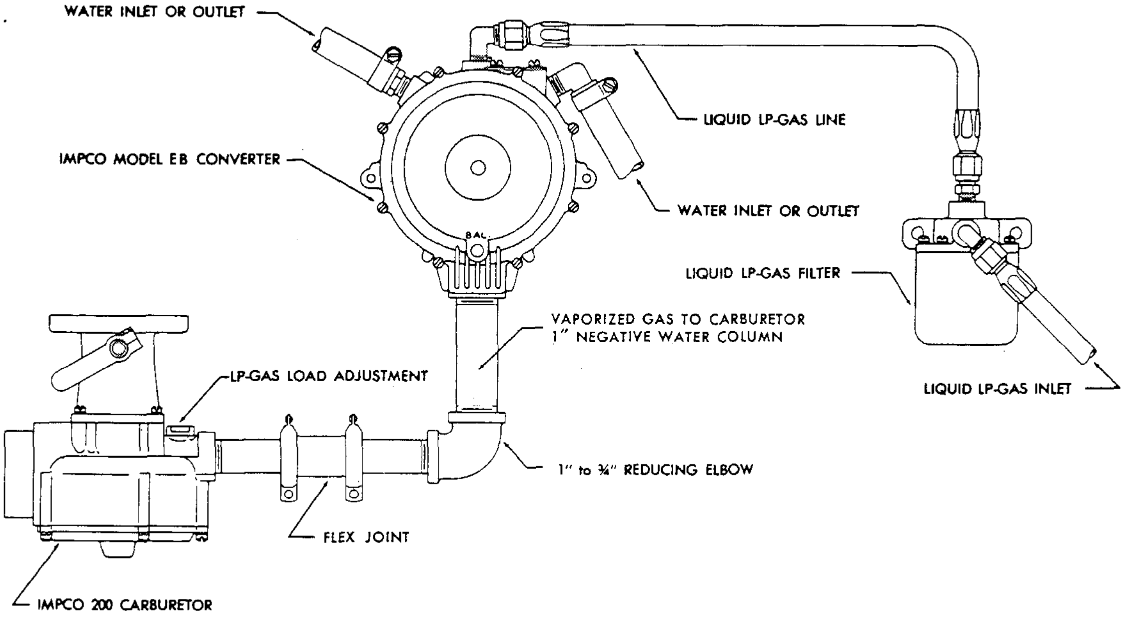


FIGURE 14 - TYPICAL LPG HIGH PRESSURE LIQUID WITHDRAWAL SYSTEM (IMPCO)

The Impco vaporizer regulator shown in Figure 14 can also be remotely mounted outside a building. With this system only vaporized gas at negative pressure enters the building.

Another system utilizes Ensign equipment as shown in Figure 15. On this system gas at tank pressure enters the remote vaporizer-regulator where it is vaporized and reduced to about 8 PSI pressure. A secondary regulator must also be used to further reduce pressure on this system. Components of the Ensign system are:

1. Tank
2. Piping
3. Wet Gas Filter
4. Vaporizer - Regulator (Primary)
5. Dry Gas Filter
6. Fuel Shut-off Valve (Electric Solenoid)
7. Secondary Regulator
8. Carburetor

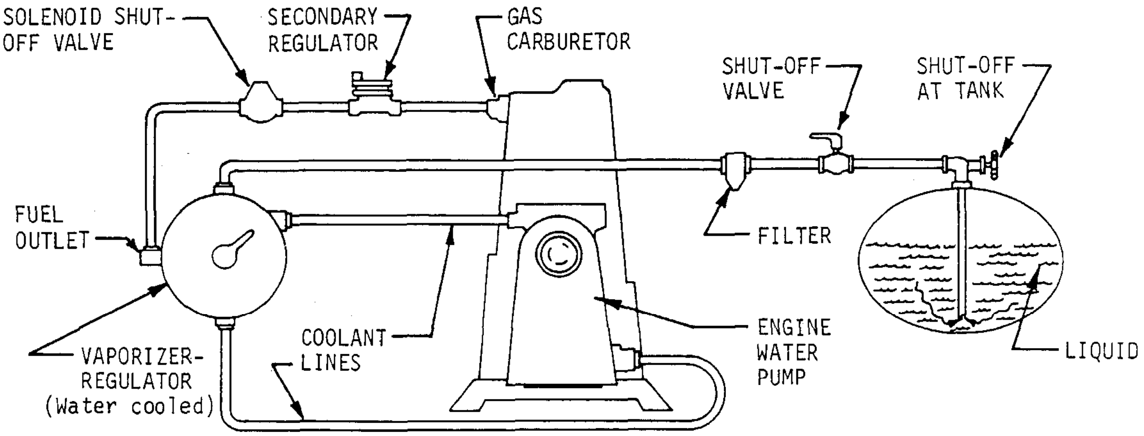


FIGURE 15 - TYPICAL LPG HIGH PRESSURE LIQUID TO 8 PSI VAPOR (ENSIGN)

NATURAL GAS SYSTEMS

Natural, manufactured and sewage gas are all in vapor state as supplied from the various utilities. The fuel systems, therefore, consist of the same basic components used in the same general sequence. When the heating content of the fuel falls below 1000 BTU, as it does with manufactured sewage and some natural gas fuels, the plant will have to be derated. A derating chart is given at the back of this manual. In addition to derating, changing to manufactured or sewage gas may involve changing carburetor venturi size and/or regulator orifice diameter to allow a greater volume of fuel to be induced.

The gas distribution company will usually provide piping from the main transmission line to the EP site. The primary regulator may or may not be furnished by the supplier. It is the responsibility of the supplier to ensure that sufficient pressure is present to operate the primary regulator. Installation, repair and alteration to gas piping should be undertaken only by the supplier or personnel authorized by him. Piping should never be used to ground any electrical apparatus. The piping should be rigidly mounted but protected against vibration damage. Where flexible connections are needed, only U. L. approved flexible connections should be used. The components of an Ensign natural, manufactured or sewage gas system are as follows:

1. Primary Regulator
2. Dry Gas Filter
3. Fuel Shut-off Valve (Electric Solenoid)
4. Secondary Regulator
5. Carburetor, Gas

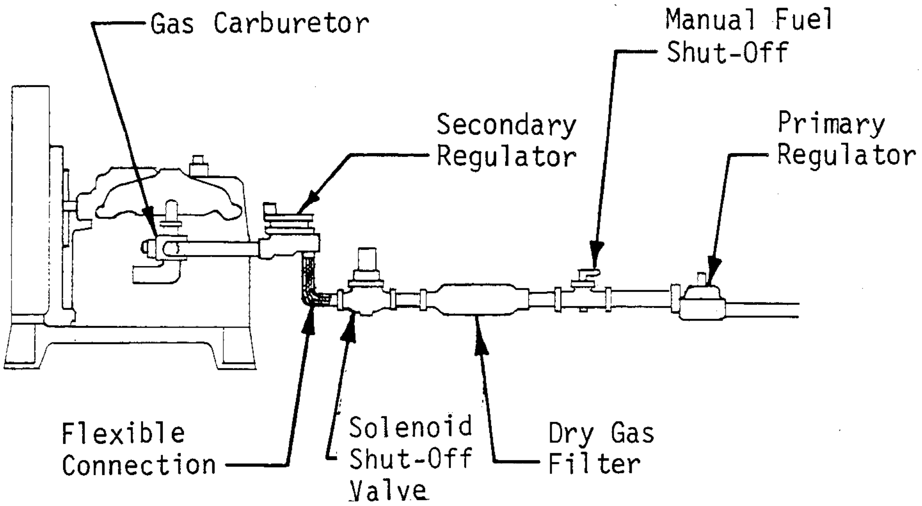


FIGURE 16 - TYPICAL NATURAL GAS FUEL SYSTEM (ENSIGN)

The Impco system functions at positive pressures rather than at atmospheric. Gas through the carburetor is controlled by the air gas valve in the carburetor. This valve measures air flow and meters gas in proper proportions according to the throttle setting and load. It seals off gas when the engine is stopped and provides automatic choke action for starting. The primary is called a "line" regulator and the secondary is called a pressure reducing valve on the Impco illustrations.

Figure 17 shows a typical layout using the reducing valve. In some applications this valve can be eliminated if the primary or line regulator can be mounted within 10 feet of the carburetor. The line regulator must then reduce pressure to 3 ounces. This is shown in Figure 18.

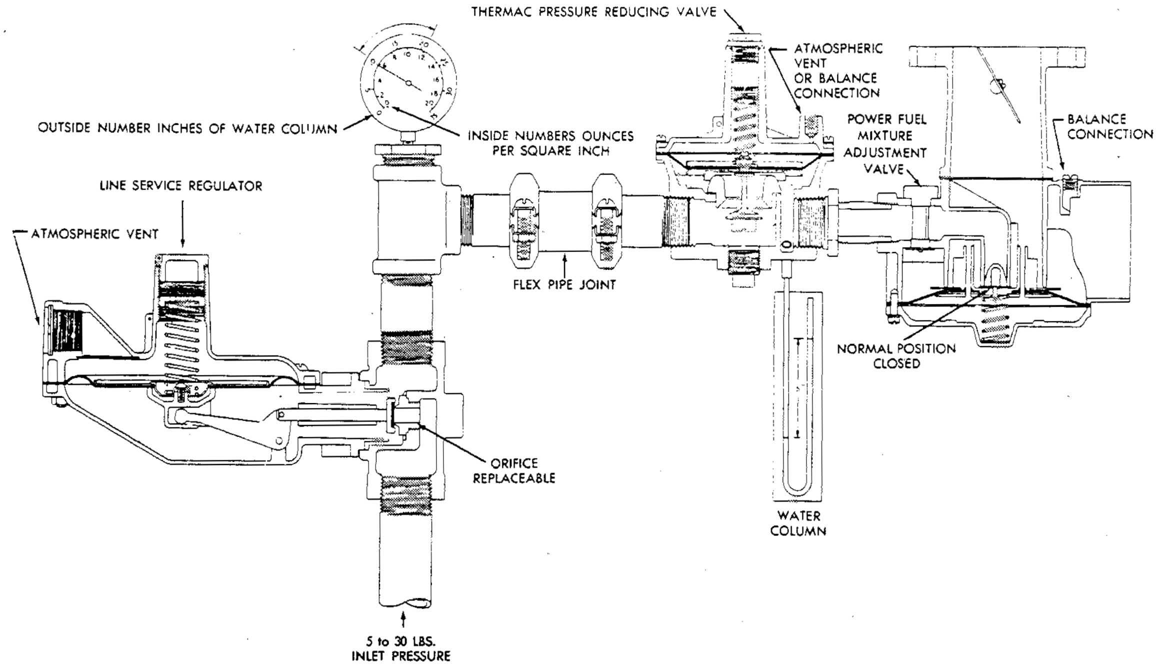


FIGURE 17 - TYPICAL NATURAL GAS FUEL SYSTEM (IMPCO)

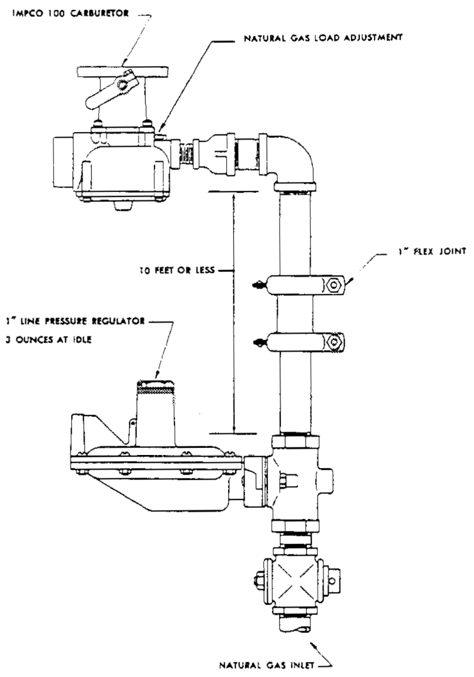


FIGURE 18 - TYPICAL NATURAL GAS FUEL SYSTEM
(IMPCO - WHERE REGULATOR CAN BE MOUNTED CLOSE TO ENGINE).

DUAL FUEL SYSTEMS (NATURAL & LPG)

In certain areas the cost of natural gas can be substantially reduced if procured on "interrupted service" rates. In many applications, LPG is used as the emergency fuel when natural gas is not available.

The Impco dual fuel system offers automatic changeover from one fuel to the other. This is accomplished by the use of two separate regulators - the secondary (line pressure) regulator for natural gas and a vacuum operated vaporizer-regulator for LPG.

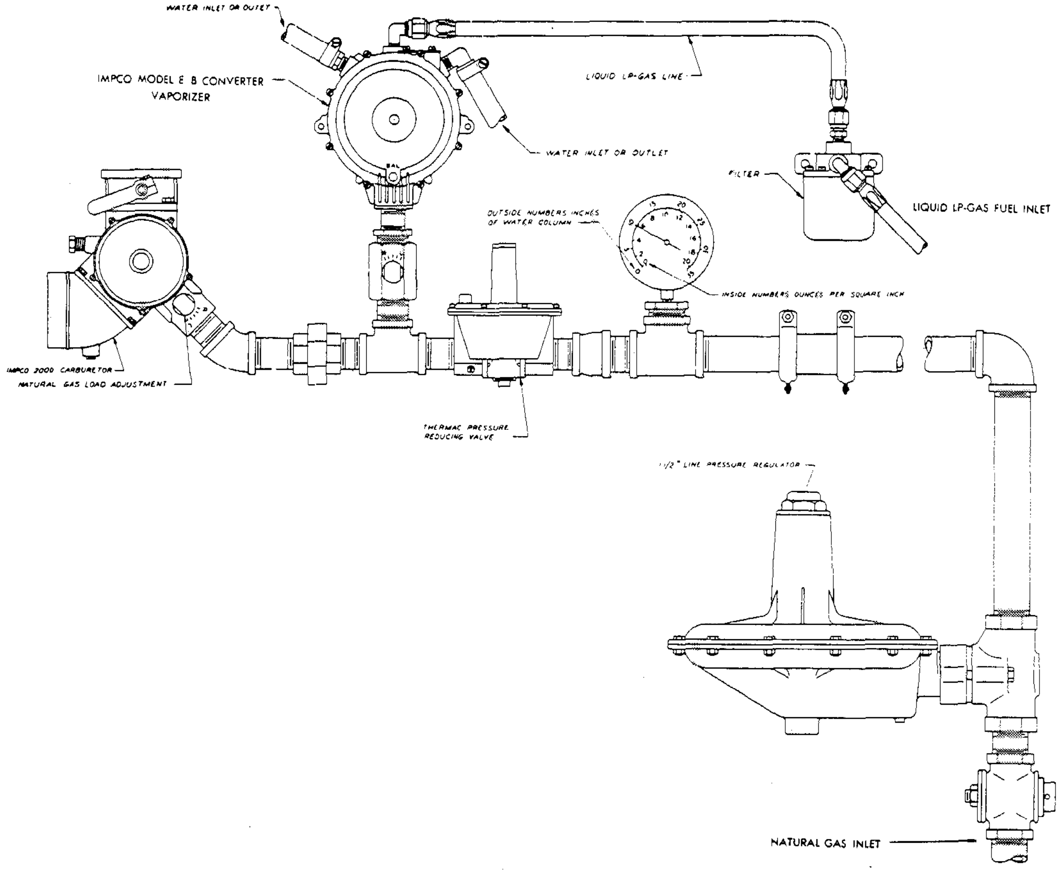


FIGURE 19 - NATURAL - LP GAS DUAL FUEL SYSTEM (IMPCO)

During operation on natural gas, the 5-inch water column pressure existing in the common line to the carburetor closes off the LPG regulator. Cutting off the natural gas creates a partial vacuum in the line which automatically opens the LPG regulator. The LPG regulator also serves as a vaporizer.

Figure 19 shows a system with the pressure reducing valve. If the primary regulator can be mounted close to the engine, and it is capable of reducing outlet pressure to carburetor to 3 ounces, the reducing valve can be eliminated.

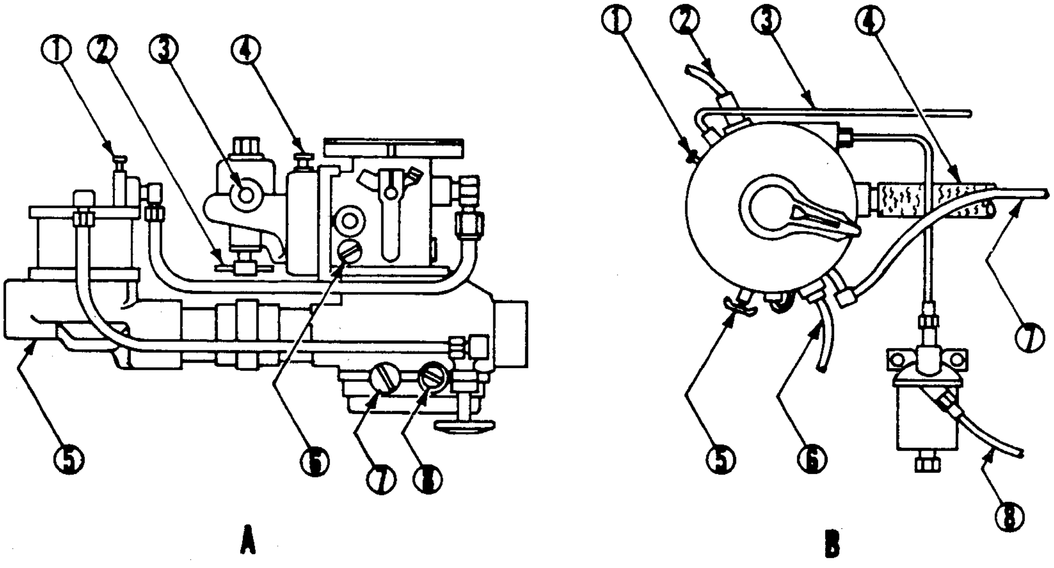
COMBINATION GAS-GASOLINE FUEL SYSTEMS

The internal combustion engine, especially the smaller models, will operate successfully on gas or gasoline without modification or complicated mechanical changeover. With the combination gas-gasoline fuel system, changeover involves only a few simple steps.

The combination system normally utilizes gas as the major fuel and gasoline only for emergency operation. In many areas natural gas is available at reduced cost on an "interrupted service" basis. Or in other cases a by-product gas may at times be unavailable. Continued operation is assured under these conditions by switch over to gasoline.

As discussed earlier, either a combination gas-gasoline carburetor or a gasoline carburetor with gas adapter or spud-in can be used. Natural, manufactured, sewage and LPG can be used with the foregoing carburetor combinations.

With the exception of the carburetor and addition of a gas adaptor, the combination gas-gasoline systems utilize the same basic components as those listed earlier under the natural and LPG systems. For this reason only the components from the carburetor to the secondary regulator will be illustrated.



1. GAS IDLE ADJUSTMENT
2. GASOLINE SHUT-OFF
3. GASOLINE INLET
4. GASOLINE LOAD ADJUSTMENT
5. GAS FUEL INLET
6. GASOLINE IDLE ADJUSTMENT
7. GAS LOAD ADJUSTMENT
8. GAS STARTING ADJUSTMENT

1. GAS IDLE ADJUSTMENT
2. WATER OUTLET
3. IDLE LINE
4. FLEXIBLE HOSE TO CARBURETOR
5. WATER DRAIN
6. WATER INLET
7. BALANCE LINE
8. GAS INLET

FIGURE 20 - COMBINATION GAS-GASOLINE FUEL SYSTEMS

Figure 20 (A) shows a combination gas-gasoline carburetor and regulator connection. This arrangement is used for natural and manufactured gas although it can be used with LPG if a separate vaporizer is used. Figure 20 (B) shows the same carburetor used with a two stage vaporizer-regulator. In both, the gas idle adjustment is made on the regulator.

Other combination systems involve the use of an adapter (or mixer) and a gasoline carburetor. The adapter can be used for all types of gaseous fuels although the venturi size should vary according to BTU content of the fuel. Increasing the venturi size reduces the volume of fuel, therefore, a larger venturi is used for the higher BTU fuels and a smaller venturi for the lower BTU fuels.

The mixer is also suitable for all fuels. On this type, gas pressure from the regulator is changed to account for variation in BTU content.

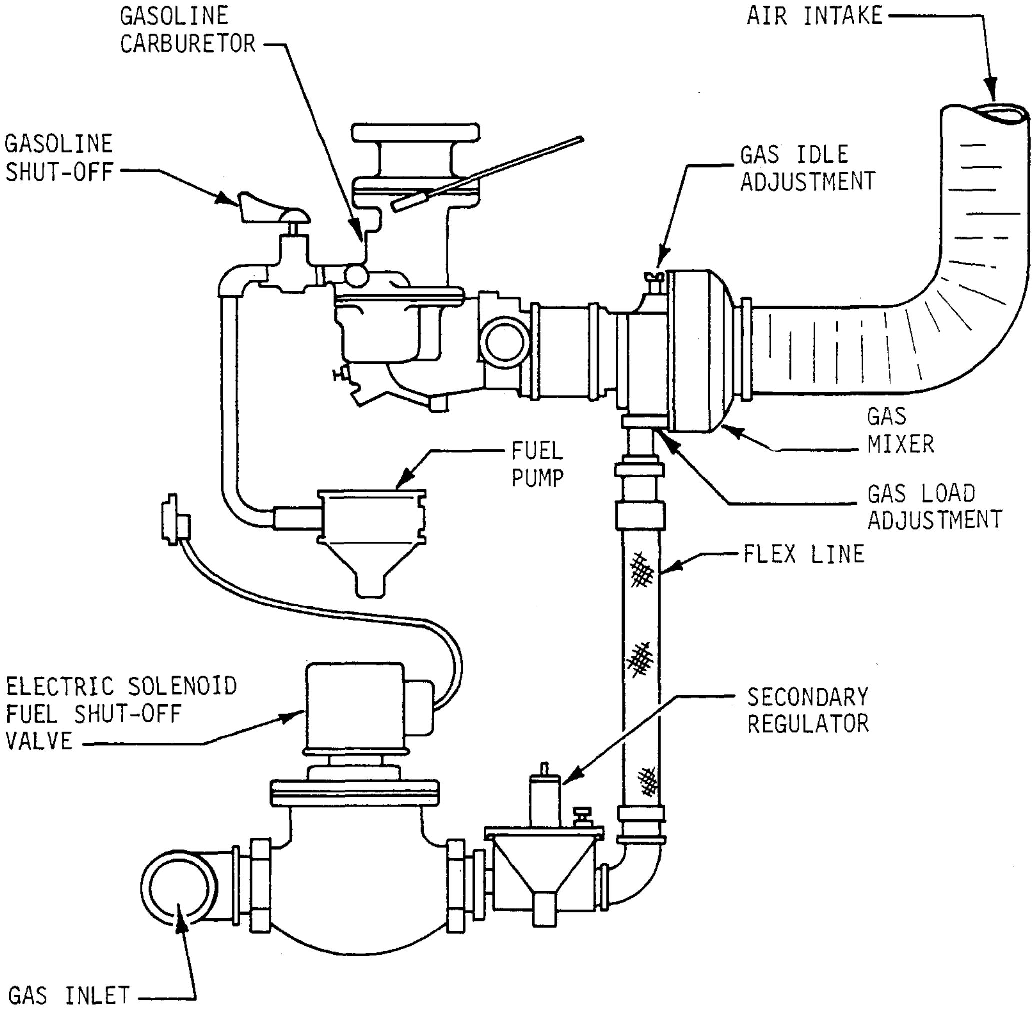


FIGURE 21 - COMBINATION GAS-GASOLINE SYSTEM WITH IMPCO MIXER

KW RATINGS - GAS FUELED ELECTRIC PLANTS

KW CAPACITY (STANDARD - GASOLINE)		LP GAS		COMB. LPG-GASOLINE		NATURAL GAS		COMB. NATURAL GAS - GASOLINE	
AIR COOLED MODELS									
1.25		—		1.25		—		1.25	
1.5		—		1.5		—		1.5*	
2.5 (K241)		2.5		2.5		2.5		2.5	
3.0		3.		3.		2.5		2.5	
3.5		3.5		3.5		3.		3.	
5.0		5.		5.		5.		5.	
7.5 (K662)		6.5		6.5		6.		6.	
7.5 (VE4)		7.5		7.5		7.5		7.5	
10.0		10.		10.		10.		10.	
15.0		15.		15.		15.		15.	
RADIATOR COOLED									
2.5 (L600)		2.5		2.5		—		2.5	
6.5		6.5		6.5		5.		5.	
10.0		10.		10.		10.		10.	
12.5		12.5		12.5		12.5		12.5	
15.0		15.		15.		15.		15.	
STANDBY (1)	CONTINUOUS (2)	1	2	1	2	1	2	1	2
30.	25.	30.	25.	30.	25.	30.	25.	30.	25.
45.	40.	45.	40.	45.	40.	45.	40.	45.	40.
55.	50.	50.	50.	50.	50.	50.	50.	50.	50.
85.	75.	80.	75.	80.	75.	75.	75.	70.	70.
115.	100.	115.	100.	115.	100.	110.	100.	100.	100.
170.	150.**	170.	150.**	170.	150.	150.	150.	150.	150.

* Derate to 1.25 KW when heating content drops below 1000 BTU.

** Limited continuous duty rating.

NOTE: 1 ø ratings of 85 KW models, 75 KW standby, 60 KW continuous except combination natural gas-gasoline, 70 KW standby, 60 KW continuous, 170 KW models, 150 KW standby, 150 KW continuous.

3 ø models .8 P.F., 1 ø models unity P.F.

Contact factory for ratings of city water cooled 85 and 115 KW.

Some 30-170 KW plants use special high compression engines on straight gas. Full KW rating allowed on these.

FUEL CONSUMPTION (CUBIC FEET PER HOUR)

ELECTRIC PLANT MODEL	ENGINE MODEL	NATURAL GAS (1000 BTU)				PROPANE - BUTANE (3000 BTU)			
		LOAD				LOAD			
		1/4	1/2	3/4	Full	1/4	1/2	3/4	Full
1.25 KW	K161	19	24	27	30	6.1	6.9	7.8	8.8
1.5 KW	K91	22	26	31	35	8	9	11	12
2.5 KW	K241	27	35	42	48	10	13	16	18
2.5 KW	L600	58	60	64	68	20	22	24	26
3 KW	K161	44	53	58	63	15	19	21	22
3.5 KW	K301	38	46	54	63	14	18	22	25
4 KW	K331	40	54	60	73	15	20	24	29
5 KW	L600	59	72	83	97	23	26	29	36
5 KW	K662	71	83	95	110	29	33	38	44
6.5 KW	L600	62	74	87	101	24	30	37	44
7.5 KW	K662	69	88	110	140	30	34	37	47
7.5 KW	VF4	100	120	144	166	38	47	55	66
10 KW	VH4	102	128	155	183	41	52	65	80
10 KW	Y-112	113	127	143	159	43	50	55	61
15 KW	VG4	190	230	273	319	56	73	87	105
10 KW	180GKB	168	195	225	255	52	61	72	82
12.5 KW	180GKB	174	210	249	285	59	62	76	95
15 KW	180GKB	182	220	268	312	60	71	87	101
30 KW	G-2300	275	320	370	418	130	145	163	178
45 KW	G-3400	370	470	570	675	108	138	172	206
55 KW	G-3400	385	490	605	725	112	145	182	220
85 KW	UV-549	445	625	820	990	180	237	297	390
115 KW	F-817G	750	940	1140	1410	240	325	420	545
170 KW	F-1197G	1180	1520	1870	2230	420	570	715	925

ENS-
552

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TI Series No. EN-4

TECHNICAL INFORMATION

KOHLER
ENGINES
in Action

ENGINE

BATTERY IGNITION
AND ELECTRICAL SYSTEMS

KOHLER CO. - KOHLER, WIS.

CONTENTS

ENGINE

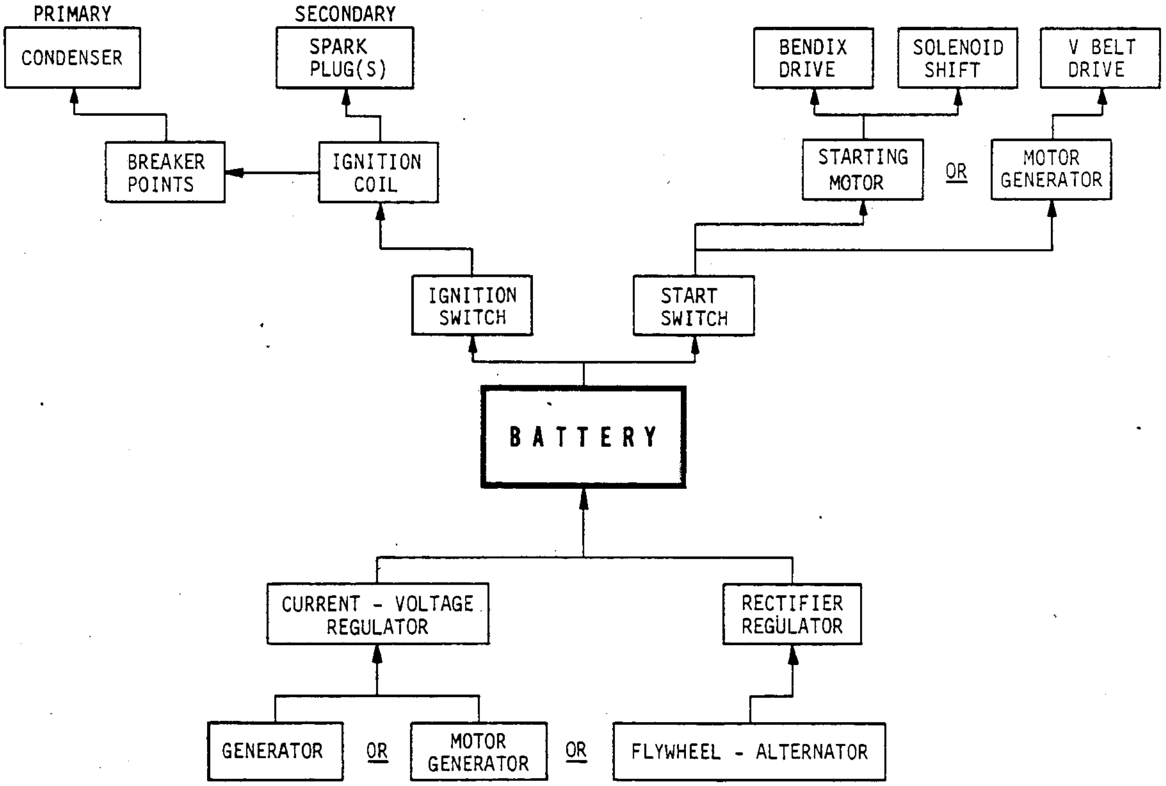
BATTERY IGNITION AND ELECTRICAL SYSTEMS

The battery ignition and electrical system serves ignition, charging, and cranking functions. In the ignition circuit, electrical energy from the battery is transformed into the high voltage necessary for ignition. The charging circuit converts mechanical energy from the engine into electrical energy which is supplied to charge the battery. The cranking circuit converts stored electrical energy from the battery into mechanical energy to crank the engine. The main components of each circuit are shown in the block diagram (Figure 1). In the cranking and charging circuits, different types of components are used to perform a specific function. For example, a generator, motor - generator or flywheel alternator may be used to convert mechanical energy into electrical energy in the charging circuit. The type used varies from model to model.

The main function of the system is to provide, at the precise instant, voltage of sufficiently high value to bridge a spark gap and ignite the highly compressed mixture of fuel and air. When we consider the relatively low (usually 12 volt) source and the fact that from 5,000 to 20,000 volts are necessary to bridge the average spark gap of .025, we realize the important job an ignition system must perform. The rate at which this high voltage spark must be delivered is also very impressive. Take for example, a single cylinder, four stroke cycle engine operating at 4,000 RPM. Since it takes two complete revolutions of the crankshaft to complete one cycle, the ignition spark must be delivered 2,000 times per minute.

In addition to the systems shown in Figure 1, a combination battery-magneto system is also used. On this, the battery, generator and starting motor serve only in cranking and charging capacities. A separate magneto system supplies energy for ignition. A flywheel alternator, battery and starting motor system is also used; however, again an external, engine-driven magneto is used for ignition.

Several entirely different principles are employed to produce electrical energy in the battery ignition system. The primary or low voltage energy is created electro-chemically in the storage battery. The generator (or alternator), which keeps the battery charged, generates electricity through a principle called electro-magnetic induction. The high voltage secondary current used to fire the spark plug is produced from still another form of electro-magnetic induction. A brief review of the basic fundamentals of these principles may further our understanding of the battery ignition system.


IGNITION - Steps up energy from the battery into the high voltage energy required for ignition.

CRANKING - Convert electrical energy from battery into mechanical energy for cranking the engine for starting.

CHARGING - Convert mechanical energy from engine into electrical energy to maintain battery in charged condition.

FIGURE 1 - SCHEMATIC - IGNITION, CHARGING AND CRANKING CIRCUITS

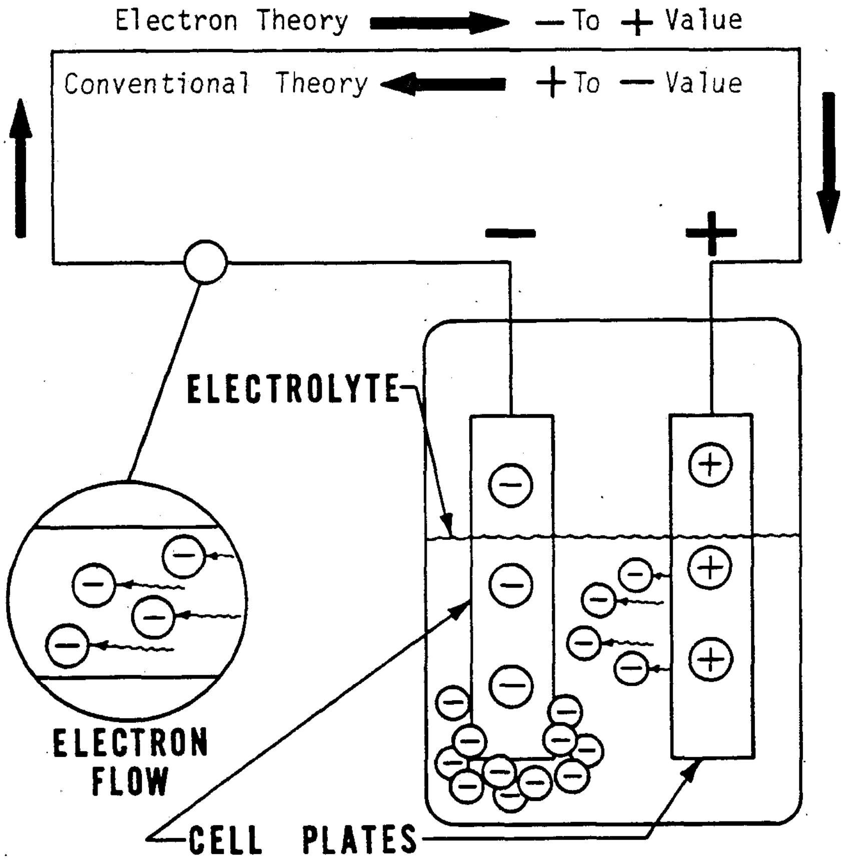


FIGURE 2
DIFFERENCE IN ELECTRICAL POTENTIAL PRODUCED IN SIMPLE BATTERY

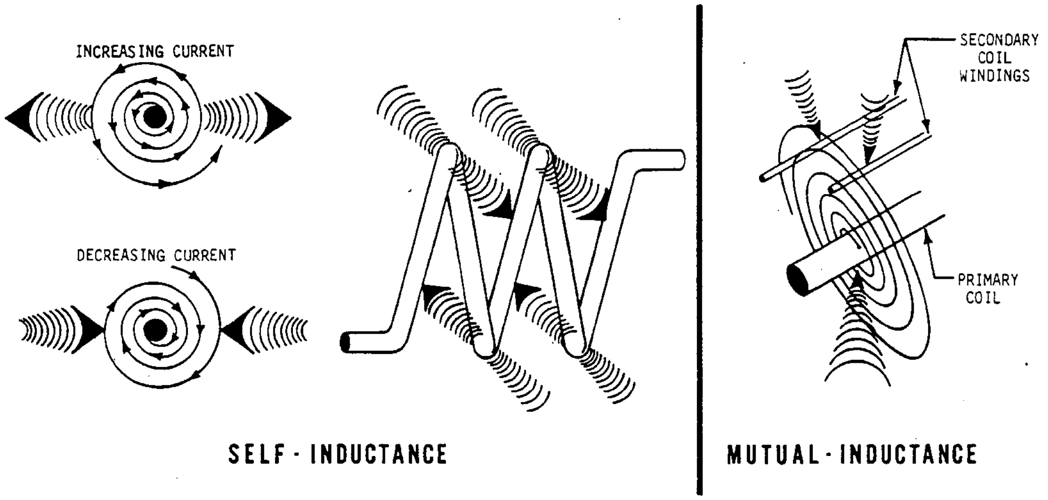
Electro-Chemical Reaction

Electron flow takes place within a conductor only when there is a difference in electrical potential and there is a complete circuit or path for electron flow. The typical lead-acid storage battery creates, by chemical action, a difference in the electrical potential. With a fully charged 12 volt battery, there is an approximate 12 volt difference between its positive and negative terminals. The terminals of a simple battery, as illustrated in Figure 2, consist of two separate cellplates of differing metallic substance which are immersed in a liquid called electrolyte. A reaction within the battery changes chemical energy into electrical charges on the cellplates. The electrolyte carries electrons away from one plate and causes a build-up or excess of electrons at the other plate. The plate that has lost electrons becomes positively charged. The electrolyte absorbs excess electrons from the negative plate but will not allow them to return to the positive plate. Connecting the terminals of the two cellplates with a conductor completes the circuit and allows the electrons to flow to the positive terminal. If this difference in electrical potential is maintained, current will continue to flow. Energy created through chemical action by the battery produces a smooth, constant, unidirectional flow of electrons.

Electro-Magnetic Induction

Whenever magnetic lines of force cut a conductor, an electro-motive force (EMF) is induced within the conductor. If the conductor is part of a completed electrical circuit, this EMF will cause current to flow. EMF is the force or difference in electrical potential that causes electrons to flow. It is not necessary that the circuit be complete in order to establish an EMF, but it must be complete to have a flow of electrical current.

As stated, the magnetic lines of force must cut a conductor. To further clarify this, the magnetic field must be increasing or decreasing in strength across the conductor to induce energy. To do this, we must have motion in the form of either stationary flux with a moving conductor or a stationary conductor with a moving flux. The generator or motor generator used in the battery system functions with a stationary flux and a moving field. On the other hand, the flywheel alternator uses a moving flux (permanent magnet ring) with a stationary field (stator). The operating principles of the generator, motor - generator and the flywheel alternator will be explained in the Charging System.



SELF-INDUCTANCE

MUTUAL-INDUCTANCE

FIGURE 3 - ELECTRO-MAGNETIC PRINCIPLES - SELF AND MUTUAL INDUCTION

In the foregoing, we have shown the principles behind production of the low voltage or primary current. To explain how the high voltage secondary current is produced, we have to delve into two other forms of electro-magnetic induction called <u>self-inductance</u> and <u>mutual inductance</u>.

Self-Inductance

The transition from low to high voltage takes place within the high tension ignition coil. This component actually has two coils--the low voltage primary coil and the secondary or high voltage coil.

Whenever current flows through a conductor, magnetic flux forms as concentric or circular lines of force at right angles to the conductor. These lines expand outward with increasing current and contract inward with decreasing current. In a coil, the field created around each loop links magnetically with adjacent loops as shown in Figure 3. This self-induced field generates a countervoltage or counter electro-motive force (CEMF) which opposes any change in the amount of current flowing.

Since this CEMF presents a momentary choking effect on increasing current, battery voltage must overcome the CEMF before the flow of current and the corresponding magnetic field can "build up" to maximum values.

The maximum is determined by the resistance of the coil itself and by the amount of time allowed for "build-up". The build-up time is relatively short; however, during high speed engine operation, ignition is normally required before the magnetic field in the ignition coil has sufficient time to build up to maximum. This means that the coil characteristics must be balanced with ignition requirements, so that sufficient energy is available for ignition even before maximum levels are reached.

The primary winding of an ignition coil is of heavy gauge, low resistance wire to allow maximum current flow and thus create a high density magnetic field through the principle of self-inductance.

Mutual Inductance

Mutual inductance is used to create the high voltage energy necessary to jump the spark gap. If a second coil is placed close to the primary coil discussed in the foregoing, the self-induced magnetic field surrounding the primary also links magnetically with this second coil. Since the secondary coil is part of a normally open circuit, an EMF is built up in the coil through mutual inductance from the neighboring primary coil.

When current in the primary reaches approximately maximum value, the circuit is broken, which causes a rapid collapse of the self-induced magnetic field. This rapidly collapsing field cuts each turn of the secondary winding and an EMF is built up in the secondary coil. In an ignition system, the secondary coil may have up to 100 times as many turns as in a primary coil. This is important since the ratio of turns in the primary to those in the secondary determines the amount of voltage "step-up" between the two. In other words, if 200 volts are induced in the primary, 20,000 volts could conceivably be imposed in a secondary having 100 times as many turns. In the ignition system, the EMF builds up only to a value sufficient to ionize or bridge the spark gap. When this occurs, the secondary circuit is complete and the resulting surge of high voltage energy across this gap ignites the fuel-air mixture.

THE BATTERY IGNITION SYSTEM

As illustrated in Figure 4, the Battery Ignition System consists of a low voltage primary circuit and a high voltage secondary circuit. In order to have a flow of electricity, there must be a complete electrical path or circuit. On the primary circuit shown, current flows from the positive terminal of the battery, through the various components, then through a common ground (engine block) back to the negative terminal of the battery which completes the circuit.

When the secondary functions, the high voltage current flows out of the secondary winding of the coil, through the high tension lead, through the center-electrode of the spark plug then across the spark gap to the side electrode which is also grounded to the engine block. With the auto-transformer type ignition coil shown in Figure 4, the primary and secondary windings are connected. On this type, the common ground, the battery and primary windings are used to complete the secondary circuit. Although the circuits are connected, very little primary current flows into the secondary since this circuit is normally open between the spark plug electrodes. The circuits therefore function as two separate systems.

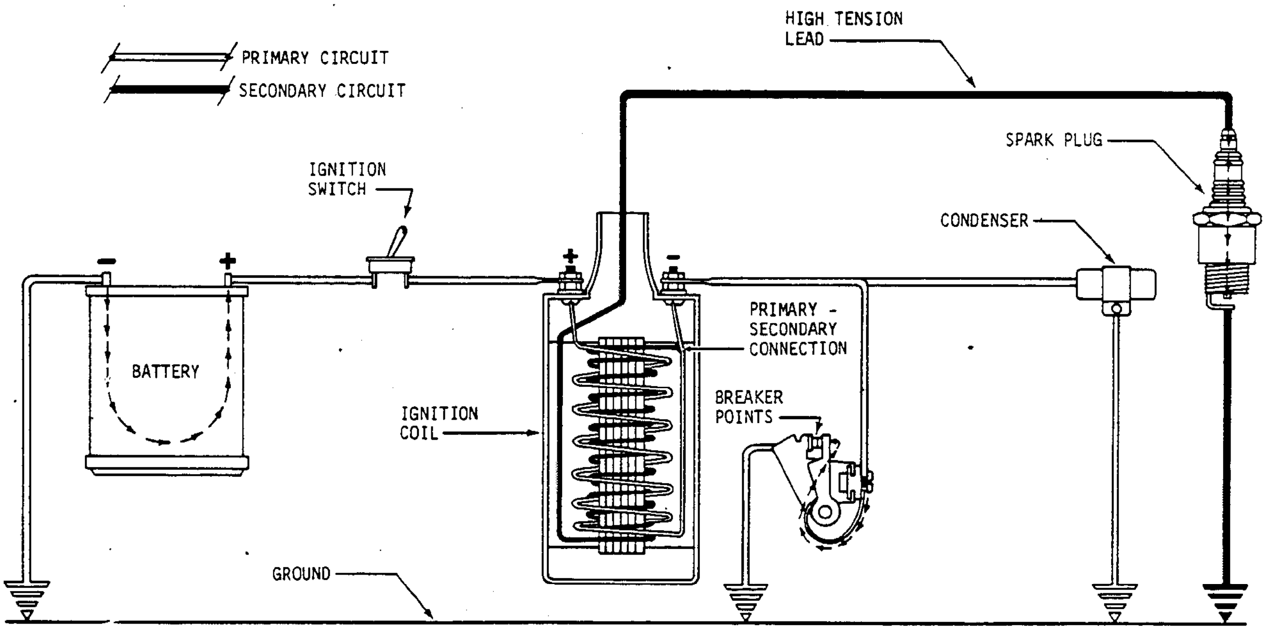


FIGURE 4 - PRIMARY (LOW VOLTAGE) AND SECONDARY (HIGH VOLTAGE) CIRCUITS

When the ignition switch is turned on, current flows from the storage battery into and through the primary windings of the coil which builds up a magnetic field. While ignition is not required, the current flows from the coil through the closed breaker points and to a common ground, then back to the battery.

When ignition is required, the breaker points are opened by the action of the breaker rod. This causes a halt in current flow in the primary winding of the coil, and the resulting sudden collapse of the magnetic field surrounding the coil windings. At this instant, the rapid change of magnetic flux causes a voltage to be induced in every turn of both the primary and secondary windings. In the primary winding the voltage, which may reach as high as 250 volts, is quickly absorbed by the condenser. The condenser thus acts as a reservoir for the surge of power in the primary coil winding. If the surge had nowhere to go, it would effect a complete breakdown of the entire function. The condenser holds this energy only for an instant after which time it is released back into the primary.

The voltage built up in the secondary, which has up to 100 times as many turns as the primary, could go as high as 25,000 volts. Normally, however, voltage does not increase to this value. It increases only to the amount sufficient to bridge the spark gap. This is usually between 6,000 and 20,000 volts. The actual value depends upon such variables as compression, speed, shape and condition of electrodes, width of spark gap, etc.

A closer look at the individual function plus construction details of the basic components may further our understanding of the ignition system.

Energy Source (Storage Battery)

The battery provides the sole source of energy for the ignition circuit. It is true that the generator replenishes energy in the battery, however, the generator does not directly supply energy to the ignition system.

The storage batteries used with engines are usually of the lead-acid type. Lead is used in the construction of the cell-plates and sulfuric acid serves as the electrolyte. Batteries are furnished in either "wet" or "dry charged" versions. "Wet" batteries are filled with electrolyte and are ready to use if satisfactory charge has been maintained. With "dry charged" batteries, the plates are charged but an electrolyte of specific grade must be added just before using. Both types function in the same way.

A typical 12 volt battery has a hard rubber case with six individual compartments or cells. Each cell contains a specific number of sets of negative and positive plates. Generally speaking, the greater the number of plates per cell, the higher the ampere-hour rating of the battery. While both positive and negative plates are of lead, the positive plates have a lead oxide covering and the negative plates a porous or spongy surface.

When the plates are surrounded by the electrolyte, a chemical reaction causes the negative plate to lose electrons and the positive to gain electrons. A difference in electrical potential is therefore built up between the two plates. All plates of like charge are interconnected so that the accumulative charges are present at the positive and negative terminals of the battery. With a battery in good condition, each cell contributes approximately

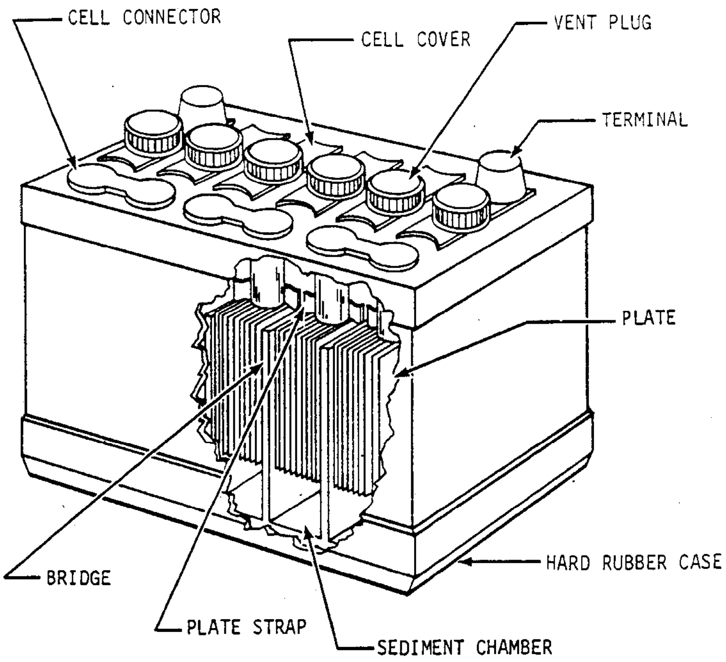


FIGURE 5 - CONSTRUCTION DETAILS - TYPICAL BATTERY

1.95 to 2.08 volts. If less than 0.05 volt difference is noted between the highest and lowest cells, the battery may be recharged but if this difference is more than .05 volts, this could indicate a cracked plate or other damage which could call for replacement of the battery.

As a battery discharges and the energy is not replenished, sulfuric acid is chemically withdrawn from the electrolyte and lead sulfate deposits continue to build up on the plates. This results in a diminishing specific gravity of the electrolyte. If this drops below 1.240, the battery must be recharged. In fully charged condition, the specific gravity will be in the 1.260-1.280 range.

As a battery is recharged, a reverse chemical reaction takes place which causes the lead sulfate deposits to be changed back to lead, lead dioxide and sulfuric acid. In effect this reverses the discharge reaction and restores materials to active condition. If sulfate deposits become too great or if the level of the electrolyte is not maintained above the level of the plates, the battery may be permanently damaged.

As a safety precaution, adequate ventilation must be provided when batteries are being recharged. In addition, sparks, open flames, and smoking should be avoided since a gas is produced which if ignited can cause an internal explosion that can shatter the battery. This gas is produced in quantity only while the battery receives high rate of charge but can linger for several hours in a poorly ventilated area.

Ignition Coil

The ignition coil functions to transform or step up the low voltage primary energy to the high voltage energy necessary to bridge the gap between the center and side electrodes on the spark plug.

The auto-transformer type ignition coil is generally used on Kohler Engines. On this type the primary and secondary windings are connected. The primary consists of about 200 turns of heavy wire and the secondary of approximately 2000 turns of very fine wire. The primary winding is assembled around the outside of the secondary winding and laminated iron is used as a center core and also to form the outer shell of the sub-assembly. This provides maximum concentration of the magnetic fields. The sub-assembly is placed in a coil case and the remaining space filled with a special oil to minimize effects of heat, moisture and vibration.

Two primary terminals are provided on the ignition coil. The positive terminal (+ marking) must be connected to the positive side of the battery. The breaker points and condenser are connected to the negative (-) terminal. Reversing these leads would cause the auto-transformer type coil to function as a step-down transformer which would, of course, make the ignition system inoperative.

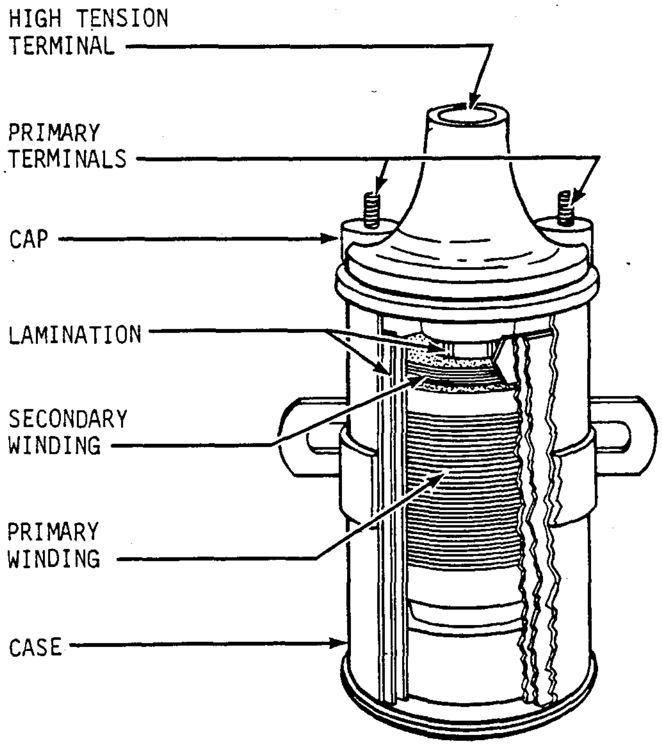


FIGURE 6 - CONSTRUCTION DETAILS - TYPICAL IGNITION COIL

Breaker Points

The breaker point assembly consists of two tungsten points which are mounted on a bracket. Tungsten is used because it is an extremely hard metal with a very high melting point and is able to withstand the continual pounding of the points closing and the eroding effect of the arc that forms when the points begin to open. On Kohler Engines, this assembly is externally mounted for ease of service and is enclosed in a metal cover to protect it against dust and moisture. The points are spring held in a closed position to provide a complete electrical circuit for the ignition system primary and are opened by the action of a breaker rod that rides on an ignition cam driven by the engine.

When ignition is required, the points are opened to break the flow of current in the primary. This causes the collapse of the magnetic field in the ignition coil which in turn induces the high voltage necessary to fire the spark plug.

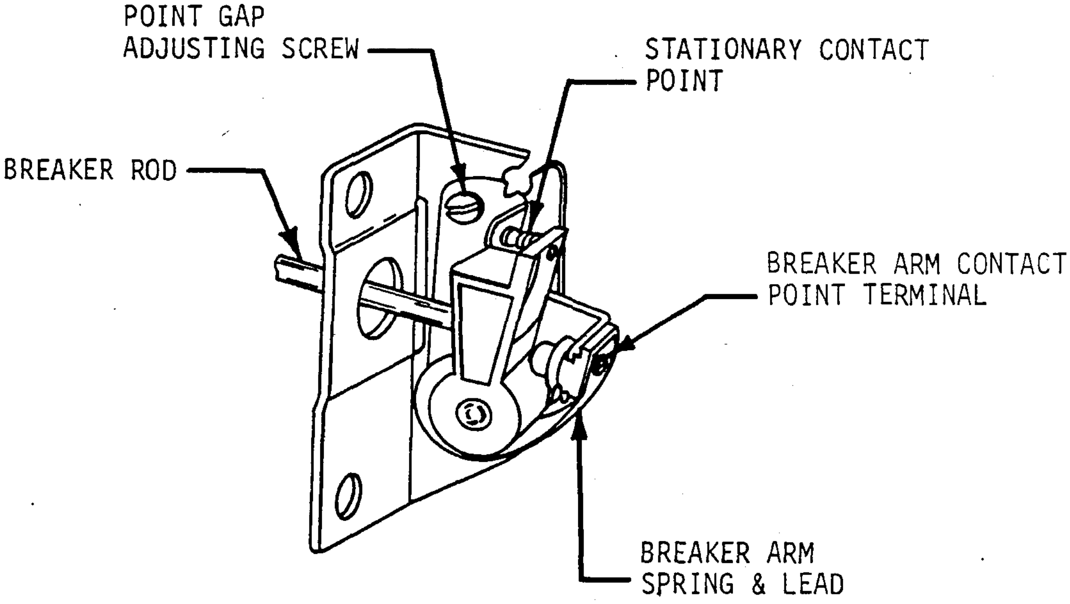


FIGURE 7 - BREAKER POINT ASSEMBLY

Condenser

The condenser performs a very important function. If it were not for the condenser, which is connected across the breaker points, current would continue to flow between the points as they separate. This current would form an arc which would burn the points and would also drain away most of the magnetic energy stored in the ignition coil in which case there would be insufficient energy left in the coil to produce the necessary high voltage surge in the secondary.

The ignition condenser provides a place where the current can flow during the first instant the points begin to separate. The energy is absorbed by the condenser instead of forming an arc between the separating points. Since a definite amount of energy is needed to produce the arc, the condenser selected must have just enough capacitance to absorb this amount of energy. A condenser with over-capacitance will cause a weaker spark to be produced while one with insufficient capacitance would obviously not be able to prevent the arc. The condenser thus acts as a storage chamber for the electrical energy.

The construction of the ignition condenser is very simple. Two strips of aluminum foil of specific length are wound together within insulating strips which separate them. One strip of foil is grounded to the container while the other is connected across the ignition breaker points.

The condenser's ability to absorb electrical charge can best be explained by the electron theory. The foil strip connected across the points absorbs the flow of electrons as the breaker points begin to separate and in so doing builds up a strong negative charge. The insulation (di-electric) separating the two strips, blocks the flow of electrons between the strips. The electrons that are bound to atoms within the di-electric are repelled and distorted out of their normal orbit, that is, they move away from the like charges of the negatively charged strip and move closer to the other strip. In so doing, they force electrons out of this strip causing it to become positive in charge. A difference in electrical potential or voltage is therefore built up between the strips. A condenser will allow current to flow only while the strips build up a charge which is only momentary. After the condenser is fully charged and the primary voltage drops, it discharges back through the primary circuit.

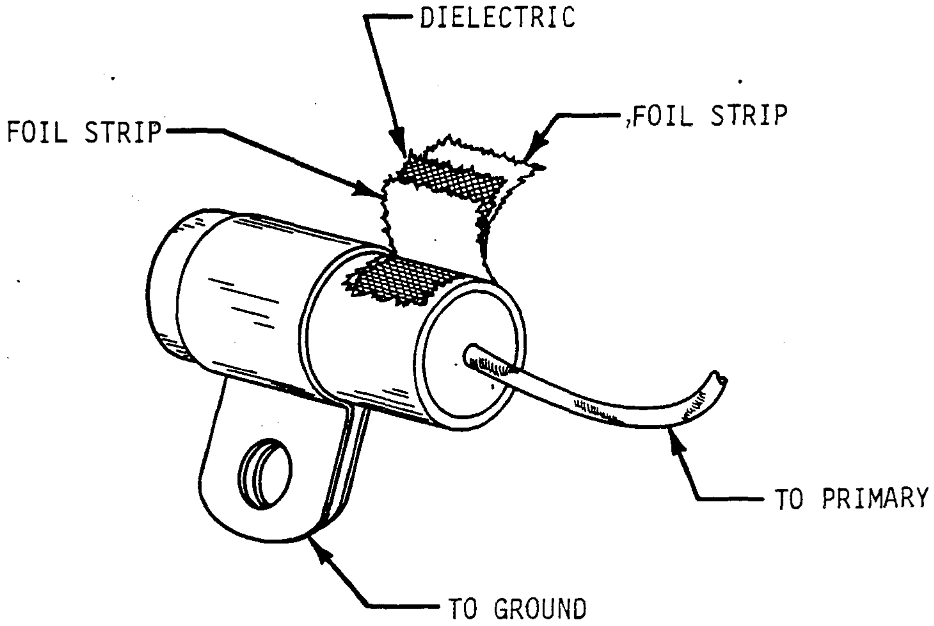


FIGURE 8 - CONSTRUCTION DETAILS - CONDENSER

High Tension Lead

The high tension lead provides a path for the high voltage current to travel from the secondary coil to the spark plug. Its core is a conductor surrounded by a heavy layer of insulation. On some applications, a metallic covering is used to contain the high frequency waves emanating from the system and thereby suppress radio interference.

Spark Plug

The spark plug is used to ignite the compressed fuel-air mixture in the combustion chamber. A typical spark plug consists of a shell, a ceramic insulator, a center electrode and a ground electrode. The two electrodes are separated by an air gap. The path of the high tension electricity is through the terminal, down through the center electrode, across the gap, to the ground electrode. The condition of the electrodes and the proper spark gap is essential to proper operation of an engine.

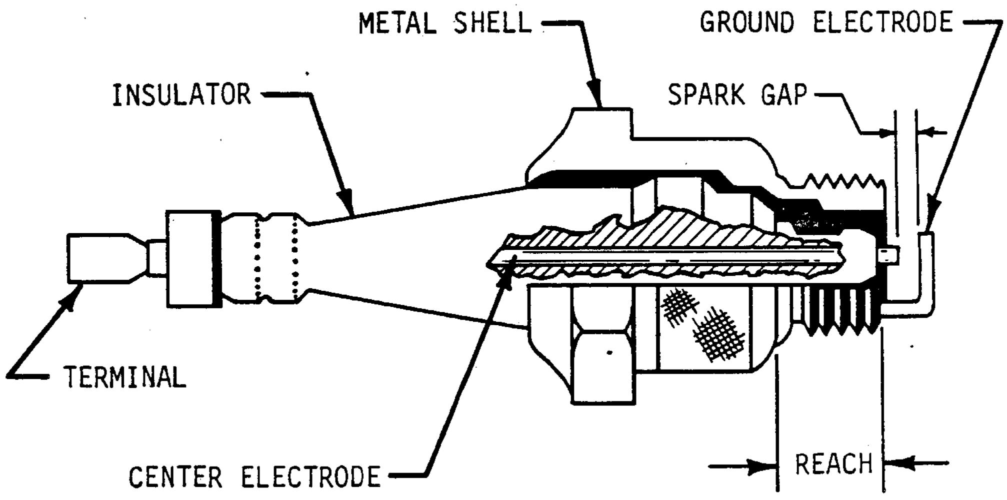


FIGURE 9 - CONSTRUCTION DETAILS - TYPICAL SPARK PLUG

TIMING — IGNITION SYSTEM

The exact timing of ignition is essential to efficient operation of an engine. The spark must occur at exactly the right moment in respect to the position of the piston in the cylinder. At the higher operating speeds, ignition must, in all cases, be started in advance of the piston reaching TOP DEAD CENTER (TDC) while at slow cranking speeds it may have to be started after the piston reaches TDC. The spark does not have to be retarded at starting on engines having the Automatic Compression Release Mechanism.

When ignition takes place in the combustion chamber of an engine, the result is not an instantaneous "explosion" of the air-fuel mixture. The flame originates at the spark plug electrodes, then in a controlled pattern, moves outward from this point into the combustion chamber. A relatively constant amount of time is required for complete combustion. During this interval of time, the pressures exerted are initially low but then build up to maximum value at about midpoint in the process.

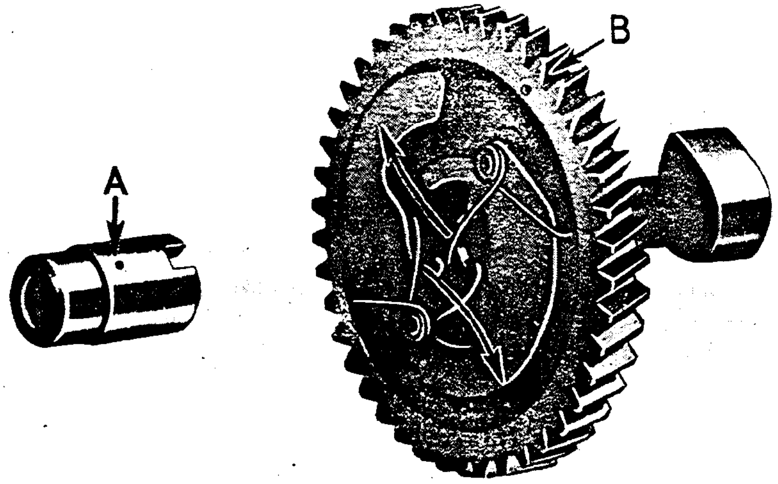
At normal operating speeds, optimum engine power is realized in having the maximum combustion pressures applied to the piston after it has reached TDC and has started downward on the power stroke. Since the time required for combustion remains nearly constant regardless of engine speed, it is necessary to ignite the fuel before the piston reaches TDC in order to realize the full force of combustion. For example, if we waited until the piston reached top dead center before starting the combustion process, the piston would be well on its way downward in its power stroke and the full force of combustion would be exerted too late to realize greatest power.

Spark Advance

Causing the spark to occur earlier in the engine cycle is called spark advance. This is stated as the number of degrees of crankshaft rotation remaining BEFORE the piston reaches TOP DEAD CENTER or BTDC. By advancing the spark, we are actually igniting the fuel charge while the piston is traveling upward on its compression stroke. If timing is correct, the highest combustion pressures are then reached just after the piston reaches TDC. In igniting the fuel charge while the piston is still on the compression stroke, it is apparent that some force is exerted which would oppose the upward travel of the piston. However, at operating speeds, inertia is provided by the flywheel to overcome this opposing force.

Automatic Spark Advance - Retard Mechanism

If no provision were made to either release compression or to retard the spark at the lower starting speeds and the ignition spark was fired at the normal spark advance point, the expanding



(A) MOVABLE IGNITION CAM (B) CAMSHAFT WITH TIMING ADVANCE ACTUATORS

FIGURE 10 - AUTOMATIC SPARK RETARD - ADVANCE MECHANISM

force of the burning gases would reach maximum before the piston had reached the top of its compression stroke, thus a backward force would be applied to the piston. "Kickback" can be dangerous and can cause serious damage to an engine since this actually tends to oppose normal rotation of the engine and at low rotational speeds, the flywheel cannot provide sufficient inertia to overcome this force.

Prior to introduction of the Automatic Compression Release (ACR) mechanism, it was necessary to provide an automatic spark retard - advance mechanism to eliminate "kickback" during cranking.

Automatic spark retard - advance was accomplished by a centrifugal flyweight arrangement that automatically shifted the position of the ignition cam with increasing engine RPM. The flyweights shown in Figure 10 are the timing advance actuators. At starting, the actuators have no affect on the cam and ignition occurs 2 or 3° ATDC. As engine speed increases, centrifugal force causes the flyweights to move outward. As they move outward, a tab provided on each actuator engages slots on the cam causing it to shift which in turn causes ignition to occur correspondingly earlier in accord with increasing speed. At approximately 800 RPM, the cam has shifted to maximum position which provides ignition at the advance point.

ACR Equipped Engines

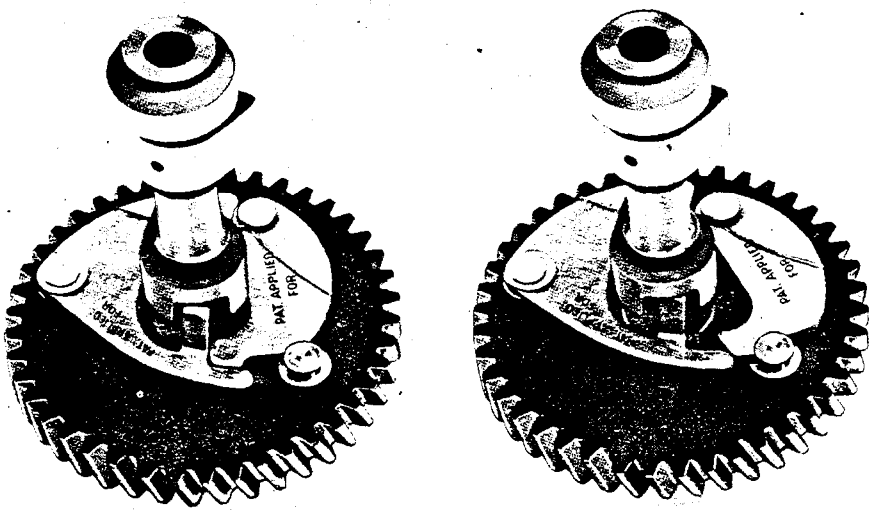
On ACR equipped engines, the spark retard mechanism has been eliminated. Releasing compression at low cranking speeds allows flywheel inertia to become greater than the expanding force of combustion, thus eliminating the cause of kickback and the necessity for the spark retard mechanism. Ignition is "fixed" at a setting of 20° BTDC on ACR engines.

The ACR consists of two weights which are activated by centrifugal force. One of the weights, called the actuating weight, is designed with a tab which acts as an overlap on the cam and trips the exhaust valve open as the piston is moving upward on the compression stroke. The other weight locks the actuating weight in position at speeds below 650 RPM. When this speed is exceeded, centrifugal force causes the free end of each of the weights to move outward which unlocks the actuating weight and drops the overlap into a cavity provided for it on the cam. Since the overlap now has no affect on the exhaust valve, all decompression action ceases and the engine operates at full power in the conventional manner.

Timing Adjustment

While timing is initially established through proper positioning of the ignition cam in respect to degrees of crankshaft rotation, it is possible to alter timing to a certain degree by shifting the point at which the breaker points open. The breaker point assembly is designed with one stationary contact and one movable contact. The movable contact is part of an adjustable breaker plate. By shifting this plate, the instant of point opening is changed in respect to movement of the ignition cam, thus causing the spark to occur either earlier or later in the engine cycle, depending on which way the plate is shifted.

The recommended point gap setting for most Kohler Engines is about .020''. The exception is the two cylinder Model K662 where the recommended setting is .015''. The dwell or cam angle refers to the number of degrees that the ignition cam rotates while the breaker points remain closed. This angle increases as the point gap is decreased. On the other hand, opening the gap wider decreases the angle and allows longer build up time since the points remain closed for a longer period.



STARTING POSITION **RUNNING POSITION**

FIGURE 11 - AUTOMATIC COMPRESSION RELEASE MECHANISM

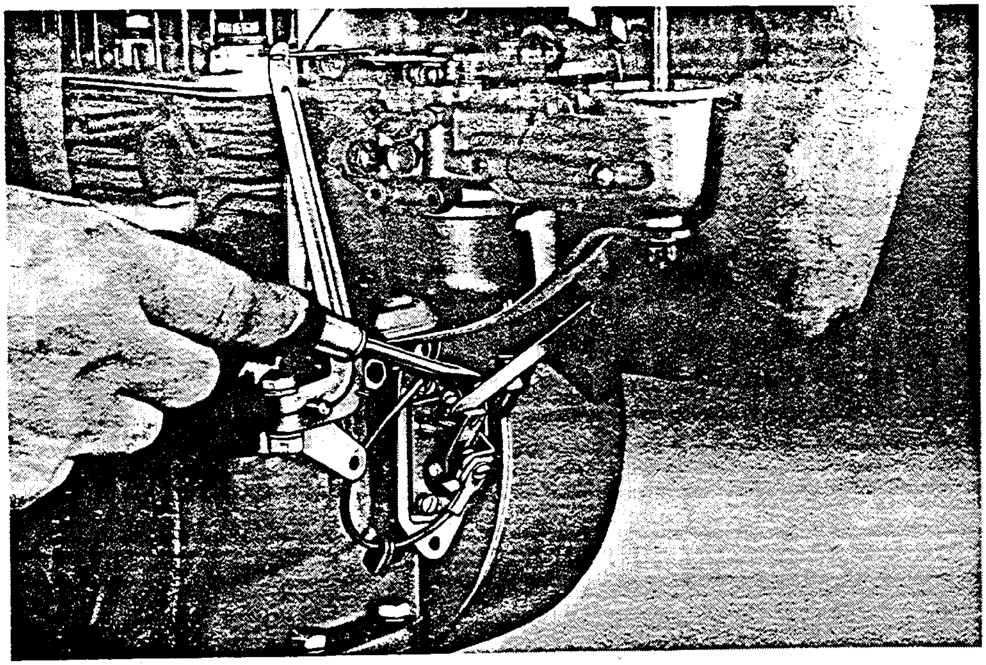


FIGURE 12 - ADJUSTING BREAKER POINT GAP

If ignition timing is adjusted to occur too early, maximum combustion pressures will be reached while the piston is still moving upward on its combustion stroke. In extreme cases, this causes severe pinging, knocking and power loss. Engine damage can also result since the combined temperatures of compression plus combustion create abnormally high temperatures in the combustion chamber. On the other hand, if the spark is adjusted to appear too late in the engine cycle, power will be wasted since the piston may be well on its way downward in the power stroke before the maximum pressures of combustion occur.

There are several methods used to achieve exact timing of the ignition spark. Since the actual timing procedure may vary from model to model, the service manual for the particular model involved should be referred to when timing the ignition system.

THE CRANKING SYSTEM

The function of the cranking circuit is to convert electrical energy from the battery into mechanical energy at the cranking motor for the purpose of turning the engine over for starting.

Motor - Generator System

An electric starting system in common use on single cylinder engines, involves the use of the motor - generator unit which is also discussed in the charging system section. These units are coupled to the engine through a V-belt - pulley drive arrangement which serves during both the cranking (motoring) and generating operations. When the unit functions as a motor, the magnetic fields of the shunt and series field combine to create forces which result in rotation of the armature. This motion is transmitted through the V-belt to crank the engine. After the engine starts, the shunt field is the main generating field and the series field functions only to limit output at the higher speeds.

Starting Motor

The operating principles of a starting motor are very similar to those of a generator and to the starting function of the motor - generator just described. When the starter circuit is activated, current flows from the battery through a commutator to the loops of wire in the armature and then through the field coils and back to the battery. The interreaction of the magnetic fields set up by the armature windings and the field windings causes the armature to revolve.

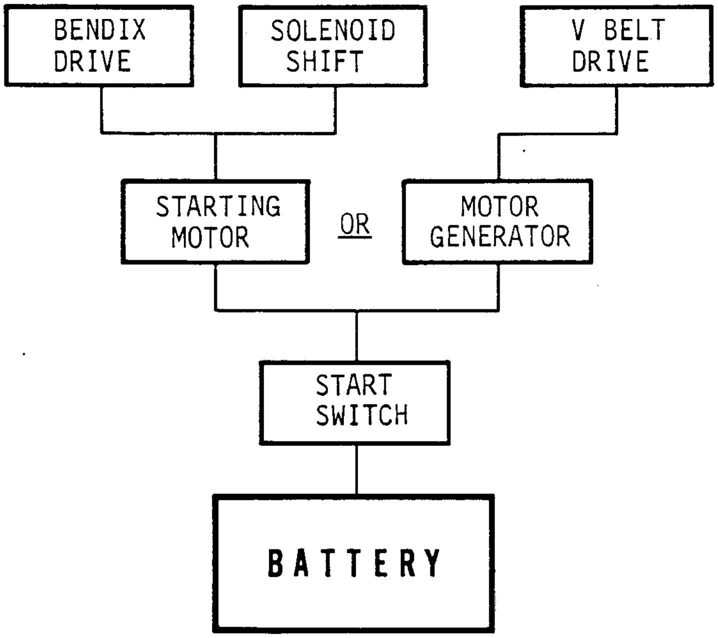
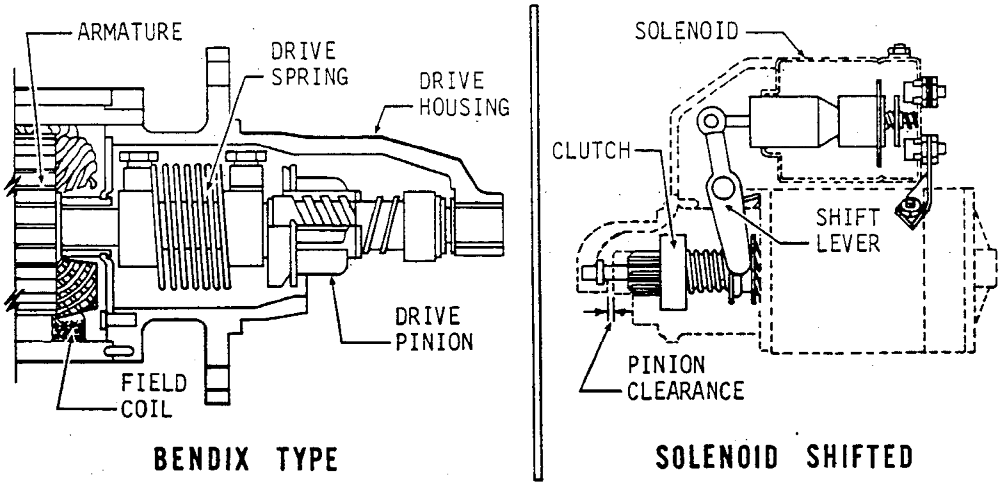


FIGURE 13 - CRANKING SYSTEM COMPONENTS



BENDIX TYPE **SOLENOID SHIFTED**

FIGURE 14 - STARTING MOTOR DRIVE TYPES

The armature revolves at a relatively high speed to produce sufficient torque to crank an engine. Since the required cranking speed is comparatively slow, the cranking motor is equipped with a small drive pinion which meshes with the teeth of the flywheel ring gear resulting in a gear reduction which varies in ratio up to 19 to 1. This permits the starting motor to develop relatively high speed and considerable power while cranking the engine at the low speeds. As soon as the engine starts, its speed quickly increases. If, for example, 1000 RPM is reached and the drive pinion remains in mesh with the flywheel, the armature would spin at 19,000 RPM, with this 19 - 1 gear ratio. To prevent damage to the armature, various devices are used which mesh the drive pinion with the engine flywheel for cranking, but disengage the two soon after the engine has started.

One of the devices used is the Bendix drive. The Bendix drive engages a pinion assembly with the ring gear on the flywheel. The pinion is mounted on a threaded sleeve which is mounted on the armature shaft. As the armature turns, the screw action of the threaded sleeve throws the pinion forward into engagement with the ring gear. After the engine has started, its speed soon overruns that of the starting motor which causes the pinion to be wound back along its threaded sleeve. The pinion is then held in retracted position by an anti-drift spring.

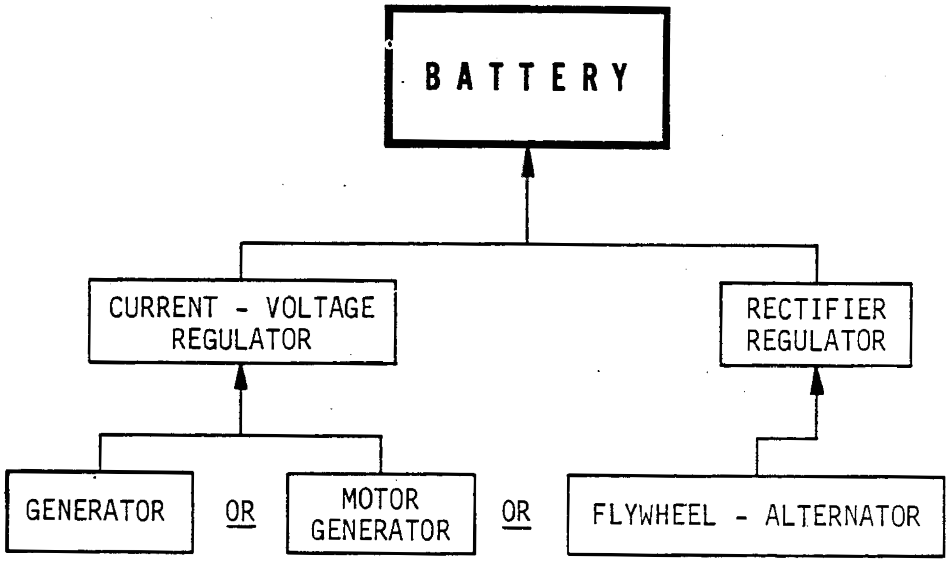
A solenoid shifted starter drive is also used on some Kohler Engines. When the solenoid is energized, it first functions to shift the cranking pinion into mesh with the flywheel ring gear. After engagement, main contacts within the solenoid close to allow battery current to flow to the motor which causes the armature to rotate and impart cranking torque to the engine. Cranking torque is imparted to the engine through a pinion-clutch arrangement. As the engine starts, the clutch allows the drive pinion to "overrun" (or to be run faster than) the armature. This offers protection against motor damage due to excessive speed. The solenoid is then de-energized which shifts the pinion out of engagement and "cuts" current to the starting motor.

THE CHARGING SYSTEM

A charging system has a dual purpose--it must generate sufficient power to supply all immediate electrical requirements and at the same time replenish energy in the storage battery. The basic components of the different systems used are shown schematically in Figure 15.

Generator

In a generator a large number of wire loops are used to increase the flow of current. These are wound around an iron core to form the assembly known as the armature. The armature is surrounded by field coils which consist of wire coiled around the pole pieces. When the armature is revolved by the mechanical action of the engine, electric current is produced in the armature windings. The field coils are connected to the armature so that a portion of the current from the armature flows through them to strengthen the magnetic field and thereby to increase the current induced in the coils of the armature.



CHARGING - Convert mechanical energy from engine into electrical energy to maintain battery in charged condition.

FIGURE 15 - CHARGING SYSTEM COMPONENTS

In order to collect the current and feed it to the battery, a device called a commutator is used at the end of the armature shaft. The commutator is divided into a number of segments which are insulated from each other, and each end of each loop of wire in the armature is connected to a commutator segment. Spring loaded carbon brushes ride on the commutator and pick up the electrical current.

The main function of the generator is to keep the battery in charged condition whenever the engine is operating. It does this by converting mechanical energy derived from rotation of the engine into electrical energy.

Motor - Generator

A motor - generator is a single unit which combines the characteristics of both a motor and a generator. As a motor, it functions to convert electrical energy into mechanical energy to crank an engine for starting. As a generator, it functions to convert mechanical energy into electrical energy to recharge the battery.

These units feature both series (cranking) and shunt (generating) windings. The cranking winding, which is in series with the armature, consists of heavy gauge, low resistance wire to carry as high a current as possible. When cranking, the current from the battery is allowed to flow through this circuit thus creating a high density magnetic field which interacts with armature windings and forces the armature to rotate. The shunt field also contributes during starting. After the engine starts and the motor switch opens to break the cranking circuit, the unit functions as a conventional generator with the shunt field producing energy for recharging. The series field is by-passed when the unit functions as a generator.

By varying the windings of the armature and field coils, the charging and starting characteristics can be changed to meet individual starting requirements. On some engines, it may be that high torque is required for starting and only a modest charging ability is necessary. Or, on the other hand, good charging ability with modest cranking ability may be desired on a smaller engine. The use of the motor - generator is generally limited to engines in the 4 to 15 H.P. range. On larger engines, a separate motor and generator must be used because cranking requirements exceed the starting torque capabilities of these units.

Current-Voltage Regulator

The regulator used with an engine is often referred to as the voltage regulator. It is actually, however, a current and voltage regulator. The type used with Kohler battery-generator systems usually consists of two units, a cutout relay and a combination current and voltage regulator unit. The cutout relay is simply a magnetic switch which opens and closes the circuit between the generator and battery when necessary. Although called regulators, the current-voltage regulators are actually limiters rather than regulators. They prevent current and voltage in the charging circuit from exceeding certain predetermined limits. Contrary to belief, they cannot raise the current or voltage by themselves and do not keep current or voltage constant in the charging circuit except during the time when they act as limiters.

The combination current-voltage regulator is a device which controls generator output and circuit voltage to meet varying battery and operating requirements. The regulator has three windings assembled on one core, a series winding of a few turns of heavy wire, a shunt winding of many turns of fine wire and a series winding of a few turns of relatively heavy wire. The heavy series winding is connected in series with the charging circuit, the shunt winding is connected across the generator so that generator voltage is impressed on it at all times. The series winding is connected in series with the generator field circuit when the regulator contact points are closed.

The windings and core are assembled into a frame. An armature is attached to the frame by a hinge so that it is positioned just beneath a stationary contact. When the regulator is not operating, spring tension holds the armature away from the core so that the points are in contact and the generator field circuit is completed to ground through them. When the contact points are open, the field circuit is completed to ground through a separate wire-wound resistor beneath the regulator base.

The current-voltage regulator action depends on both the current flowing through the series (load) winding and the voltage imposed on the shunt winding. The field current winding also has some effect.

When the generator goes into operation, the voltage imposed on the shunt winding causes some current to flow thus creating a magnetic field. Closing of the cutout relay allows current to flow through the load winding creating an additional magnetic field. When these two magnetic fields add up to sufficient strength, they pull the regulator armature toward the core causing the contact points to open. This diverts the field current to ground through the wire-wound resistor. The additional resistance of this circuit causes the generator voltage and output to drop. This, in turn, causes a weakening of the combined magnetic field from the load and shunt windings, so that the armature spring tension pulls the armature away from the core and the contact points close. Generator voltage and output then immediately increase, strengthening the magnetic field and causing the points to open again. This cycle is rapidly and continuously repeated as long as the generator and regulator are in operation, thus accomplishing the required control of the generator voltage and output.

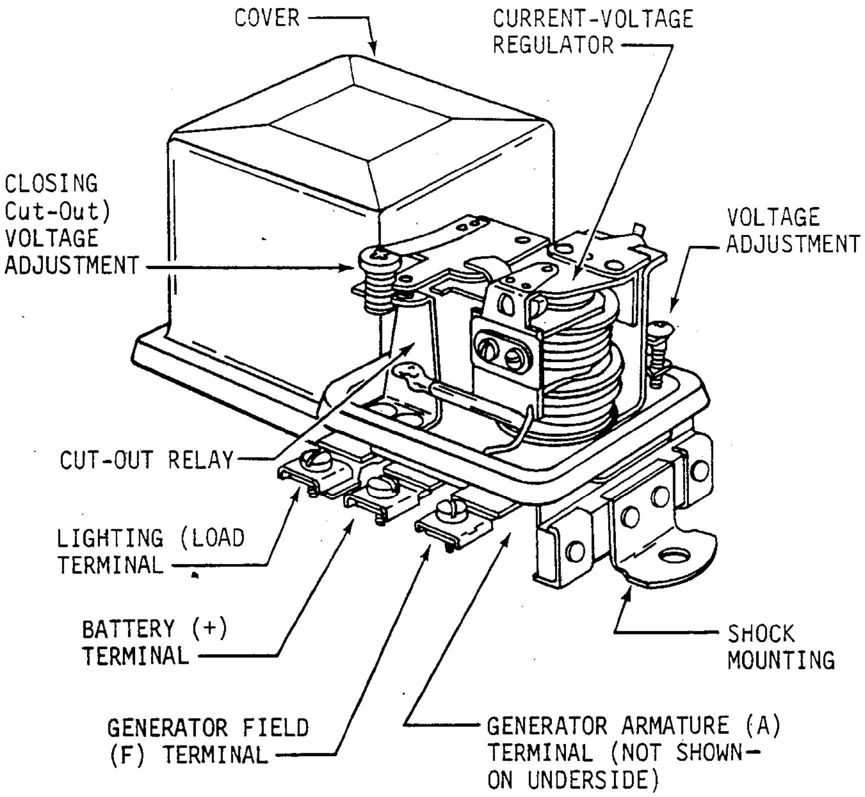


FIGURE 16 - CURRENT - VOLTAGE REGULATOR, TWO UNIT TYPE

The field current winding might be termed an accelerator winding that speeds the action of the regulator armature in closing and opening the points. When the contact points are closed, the field current flows through the winding creating a small magnetic field. The strength of this field adds to the magnetic field strength of the shunt winding and helps to attract the armature. As the points open, current stops flowing through the field current winding, and its magnetic field collapses. Since this causes an appreciable weakening of the total magnetic field holding the points open, armature spring tension causes the points to close quickly. This results in an increase in the rate of armature vibration.

Since the electrical resistance of the regulator windings is lower when they are cold than when they are thoroughly warmed up, the voltage required to force a given current through the windings also varies. This condition would cause the regulator to operate at a considerably higher voltage when hot than when cold if the regulator were not compensated for temperature. Therefore, the current-voltage regulator includes a temperature compensating device in the form of a bi-metal hinge on the regulator armature. The action of the hinge provides increased spring tension when the regulator is cold and reduced spring tension when warm, thus offsetting the effect of changes in the electrical resistance of the windings with temperature.

The cutout relay is a device which closes the circuit between the generator and the battery when the generator is operating at sufficient speed to charge the battery and which opens this circuit (when the generator slows down or stops) to prevent the battery from discharging back through the generator. The relay has two windings assembled on one core, a series winding of a few turns of heavy wire and a shunt winding of many turns of fine wire. The shunt winding is connected across the generator so that generator voltage is impressed upon it at all times. The series winding is connected in series with the charging circuit so that generator output passes through it.

The relay core and windings are assembled into a frame. An armature is attached to the frame by a hinge so that it is centered just above the end of the core. The armature has one contact point which is located just above a similar stationary contact point. When the generator is not operating, the armature contact point is held away from the stationary contact point by the tension of a flat spring riveted on the side of the armature.

When the generator voltage builds up to a value great enough to charge the battery, the magnetism induced by the relay shunt winding is sufficient to overcome the armature spring tension and pull the armature toward the core so that the contact points close. This completes the circuit between the generator and battery. The current which flows from the generator to the battery passes through the series winding in the proper direction to add to the magnetism holding the armature down and the contact points closed.

When the generator slows down or stops, current begins to flow from the battery to the generator. This reverses the direction that the current flows through the series winding, thus causing a reversal of the magnetic field of the series winding. The magnetic field of the shunt winding does not reverse. Therefore, instead of helping each other, the two windings now magnetically oppose so that the resultant magnetic field becomes too weak to hold the armature down. The flat spring pulls the armature away from the core so that the points separate; this opens the circuit between the generator and battery.

With an electrical load, such as lights, turned on, the generator output increases. The regulator has an extra terminal marked "L" which is connected with the lower contact point in the cutout relay. This extra terminal permits current from the generator to be diverted to the load without its passing through the current-voltage regulator. This current has no reducing effect on the operating voltage since the regulator is affected only by current going to or from the battery. Generator output, therefore, is allowed to increase to a value sufficient to handle the load and still supply a charging current to the battery, provided, of course, that the total current requirements do not exceed the maximum output of the generator.

Lights, ignition and all other similar loads attached to the "L" or load terminal of the regulator will not interfere with regulation. Any load (such as a horn), however, which may individually exceed the total output of the generator, must be connected directly to the battery side of the ammeter. Heavy currents cannot be drawn from the battery through the series winding of the current-voltage regulator without considerable increase in operating voltage.

Care must be taken to prevent interchanging the leads at the "L" or load terminal and the "BATTERY" terminal of the regulator. Loads, such as lights, connected to the "BATTERY" terminal of the regulator will prevent proper operation. Only the battery should be connected to the "BATTERY" terminal of the combined current-voltage regulator.

Flywheel Alternator System

A flywheel alternator system is also used to supply electrical energy to charge the 12 volt battery which in turn furnishes energy for ignition, cranking and also for lighting circuits on some applications.

While the generator and motor-generator both function with stationary flux and a moving conductor, the flywheel alternator uses a stationary conductor (stator) and a moving flux (magnet ring). The flywheel alternator system consists of the following basic components:

1. Permanent field magnet ring.
2. Alternator stator assembly.
3. Rectifier - regulator assembly.

The magnet ring has a specific number of permanent magnets imbedded in a cast ring. These high strength ceramic magnets are arranged between pole pieces, so that there is an equal number of north and south magnetic poles. This is illustrated in Figure 17. The magnet ring is permanently fitted to the inside rim of the engine flywheel so that it can be rotated around the alternator stator which is assembled in stationary position on the closure plate of the engine.

The alternator stator assembly consists of soft iron laminations which are stacked to form a core for the conductor or the coil windings. The conductor is wound around the core posts to form individual coils. The ends of this primary (load) conductor are connected to terminals on the rectifier - regulator assembly. A second conductor is also wound around each of the posts. This forms a secondary coil or regulator winding which will be discussed later.

Whenever magnetic lines of force cut a conductor which is part of a complete electrical circuit, an electrical current will be induced in the conductor. To explain how alternating current is induced in the primary windings, refer to the coil in the 12 o'clock position in Figure 17. In this illustration, a south magnetic pole piece is just above the reference coil. When in this position, the magnetic lines of force move out of the adjacent north pole pieces, downward through the adjacent core posts, then upward through our reference coil to return to the magnets through the south magnetic pole piece. The direction of flux is important as it also determines the direction that the current flows through the windings. For example, when a north magnetic pole piece rotates above our reference coil the flux direction is opposite of what it was when the south pole was in the same position. Since the flux direction is reversed, the direction of current through the primary windings is also reversed. This current continually changes direction, since the pole pieces are alternately north and south. The alternating current (AC) thus produced must be changed into direct current (DC) to be used in the battery and ignition system.

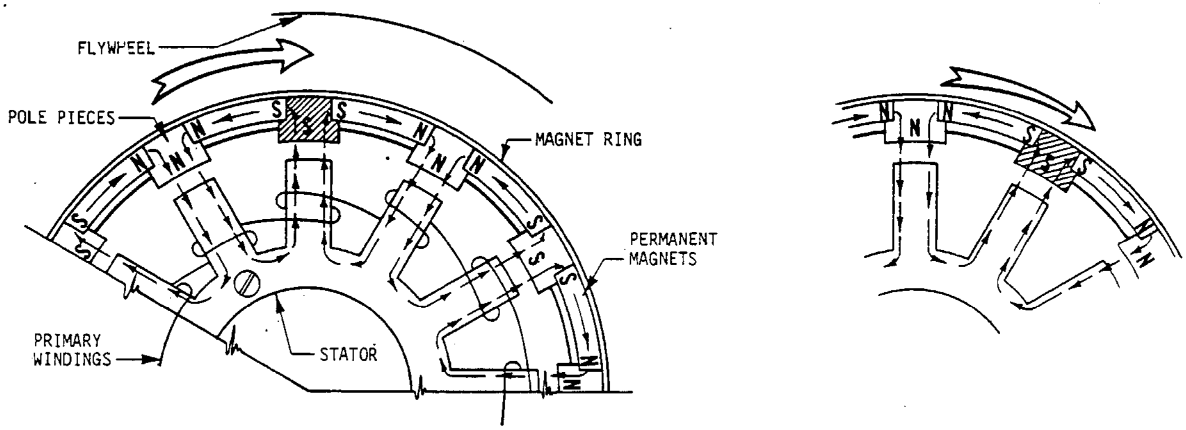


FIGURE 17 - ALTERNATING CURRENT PRODUCED BY FLYWHEEL ALTERNATOR

Alternating current is changed to DC in the rectifier portion of the combined rectifier - regulator assembly. The rectifier consists of four solid state (no moving parts) electronic devices which are pressed into two aluminum cooling fins.

The electronic devices are diodes which is the term used to describe a simple two-element type of rectifier. In these, one element has good conducting properties while the other is of a semi-conductor substance. The elements are arranged so that they offer very little resistance to current flow in one direction but block current flow of the opposite direction.

A single diode placed in an AC circuit will rectify the current to a pulsating direct current. For example, a positive diode would allow only current on the positive alternation to flow and would block the return or negative alternation. This would be called a half wave rectifier since only 1/2 of the current produced would be available as an interrupted or pulsating flow of DC.

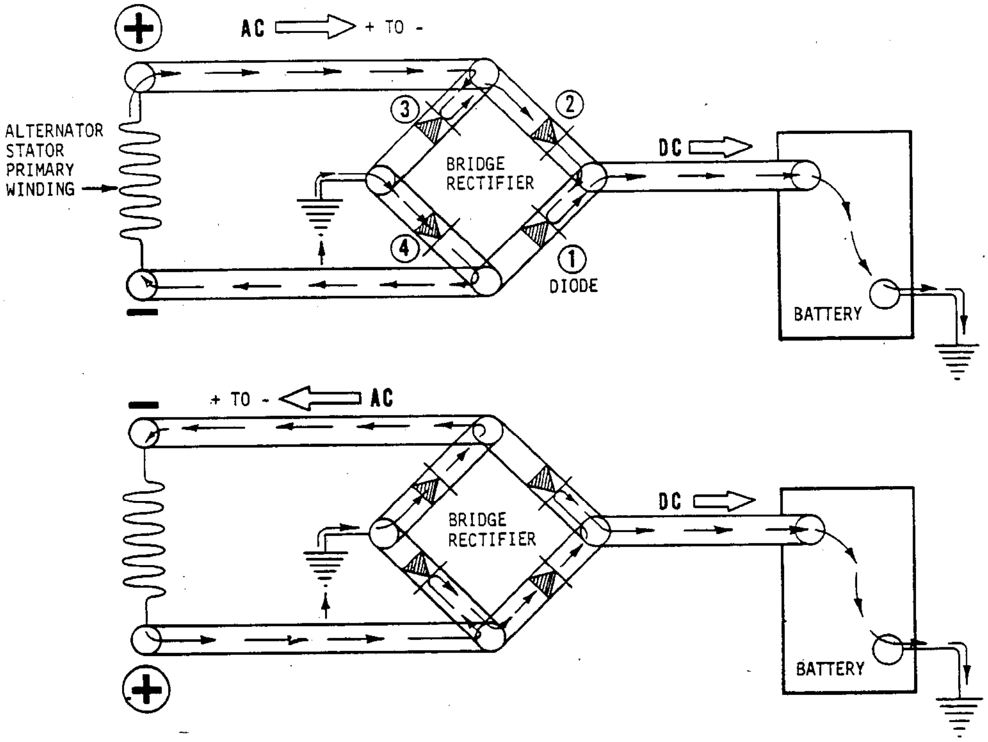


FIGURE 18 - FULL WAVE BRIDGE RECTIFIER

By using four diodes and arranging these to form an electrical bridge, both positive and negative alternations of the AC can be rectified into a relatively smooth, unidirectional flow of Direct Current. The function of the full wave bridge rectifier is shown schematically in Figure 18.

Control of the battery charging rate is provided by a separate regulating circuit which also uses solid state electronic devices. The main components of the regulating system are:

1. Zener Diode
2. Silicon Controlled Rectifier (SCR)
3. Regulator Winding (In Stator)
4. Variable Resistor (Rheostat)

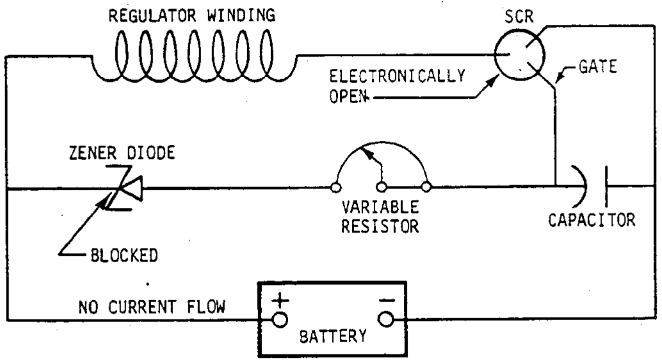
Relating these components to parts with similar function in the conventional current-voltage regulator; the Zener diode can be visualized as the relay coil, the SCR as the switching device or contacts, and the variable resistor as the adjustable contact return spring.

While the conventional current-voltage regulator measures and regulates generator output, the regulator used with the flywheel alternator "senses" the voltage of the battery to control output. An electronic device called a Zener diode is used as the voltage sensing device.

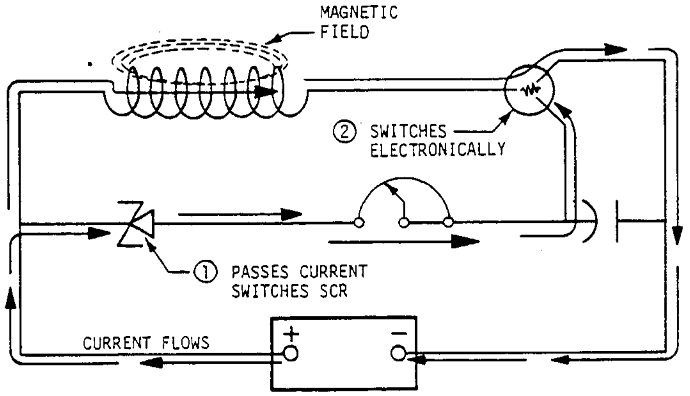
When the battery is low and in need of charging, the regulating circuit does not function and the battery is charged at full capacity by the alternator. During this time the Zener diode blocks or prevents current from entering the regulating circuit. When the battery comes up to charge and its voltage increases to a specific level, the voltage forces the Zener to "breakdown" electrically and pass current which then flows through the variable resistor and momentarily into the capacitor (See Figure 19). This energy is applied to the gate or control element of the SCR which in turn switches electronically to complete the regulating circuit.

As current flows through the regulator winding, it builds up a magnetic field which reacts with the field of the primary windings. The charge rate is thus controlled since any increase in current through the regulator winding brings a corresponding decrease in current through the primary windings. In other words, when a high charge rate is needed, little or no current flows in the regulator windings and when no charging is required, maximum current will flow in the regulator windings.

The charging rate can be increased or decreased to a certain degree by adjusting the variable resistor. This is called out as the "Voltage Adjustment" in Figure 20 which shows the regulator with the cover removed. Since heat produced by the solid



NO REGULATION - BATTERY VOLTAGE LESS THAN "BREAKDOWN" VOLTAGE OF ZENER DIODE



REGULATION - BATTERY VOLTAGE EXCEEDS "BREAKDOWN" VOLTAGE OF ZENER DIODE

FIGURE 19 - FLYWHEEL ALTERNATOR REGULATING CIRCUIT

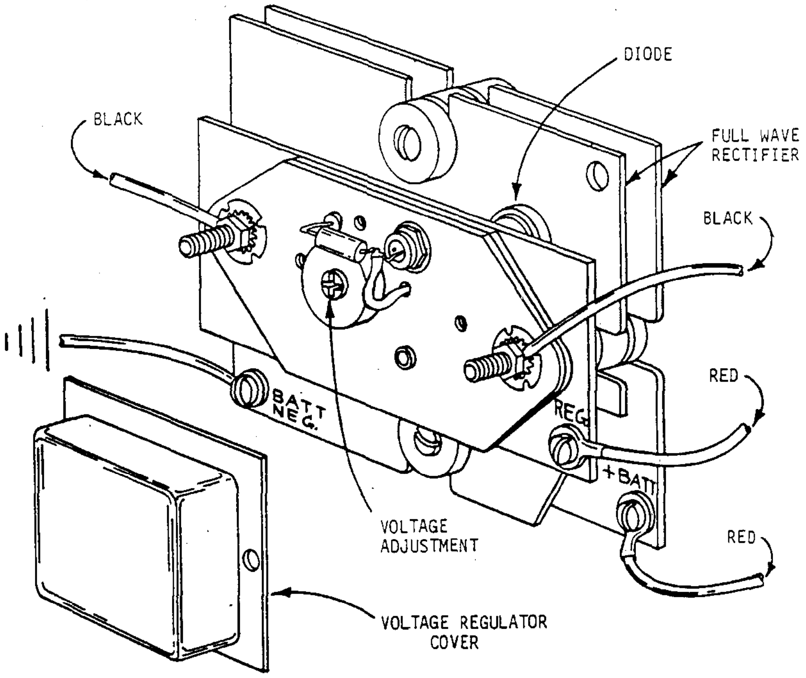


FIGURE 20 - RECTIFIER - REGULATOR ASSEMBLY

state devices must be efficiently dissipated, the fins must be mounted in a vertical position to provide maximum cooling.

In addition to the ignition, cranking and charging systems described, lighting or accessory systems are also frequently used. Although these systems derive energy from the battery and can, if malfunctioning, effect engine performance, they are not discussed in this manual since their function is not directly related to operation of an engine.

TECHNICAL INFORMATION SERIES

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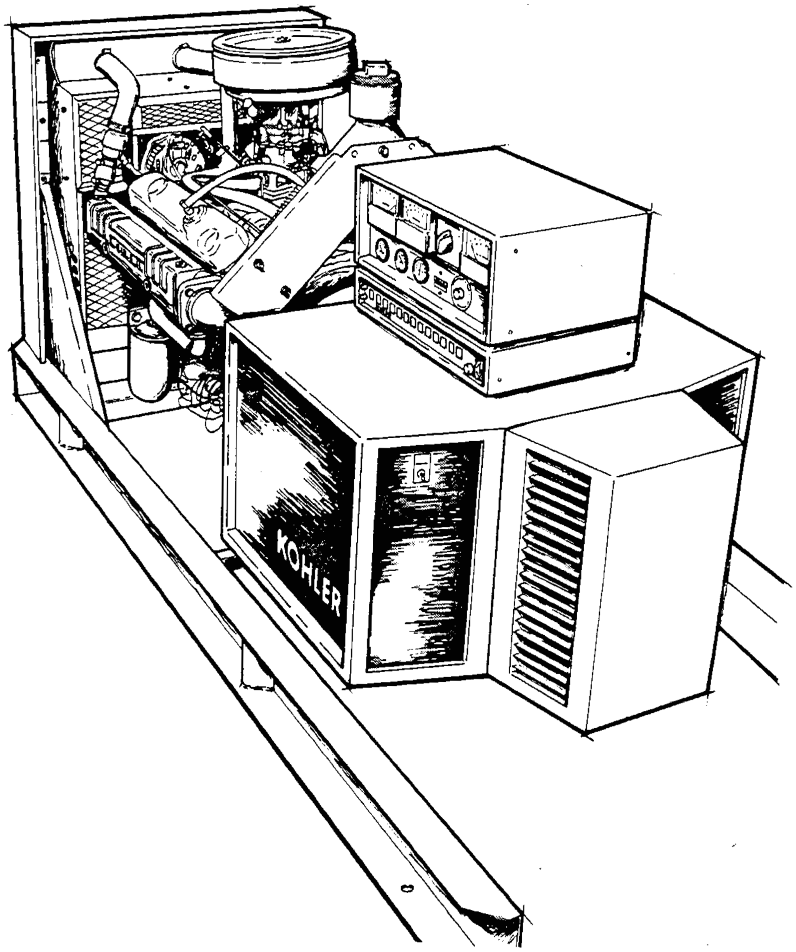


Stationary Duty

INSTALLATION GUIDE

ES-420

Table of Contents

Introduction

The proper functioning and successful operation of a generator set depends primarily on the initial installation. See Figure 1. If done properly, the set can give years of dependable service. If not done properly, it can cause continuing problems. Your Kohler Generator Distributor will be able to provide you with advice and assistance on your particular model. Refer to the "Application Data" section at the back of this manual and your model's Specification Sheet for specific details - use these as a guide for planning the particular requirements of your installation. It cannot be stressed too strongly that if proper coordination and proper planning is done, and the initial installation is correct, many dollars will be saved in subsequent years of troublefree operation.

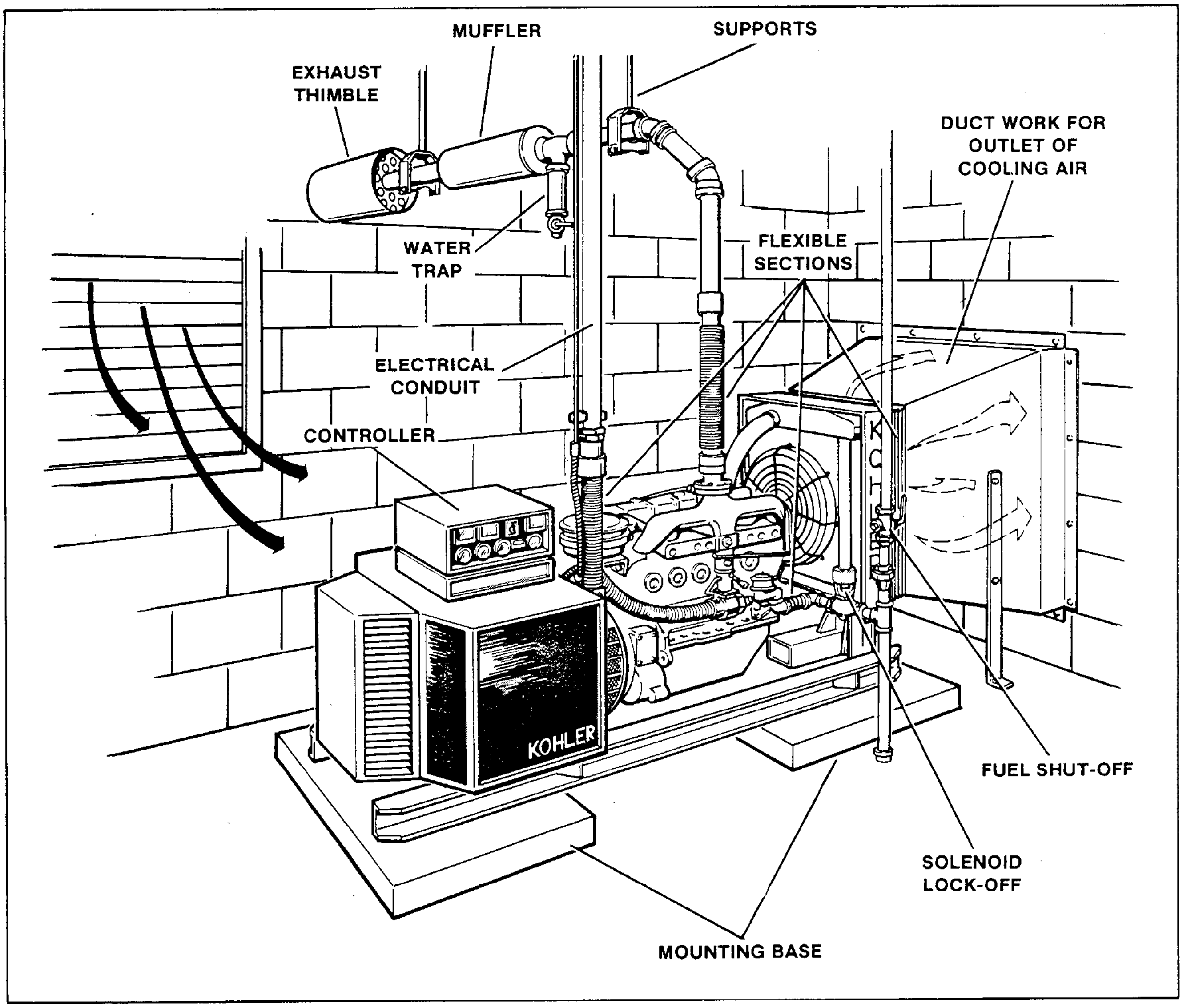


Figure 1. Typical Stationary Duty Generator Set Installation

Safety Precautions

Safety is built into every engine driven generator; however, like any other electro-mechanical device it can present a serious threat to life and limb if imprudently operated and maintained. Remember that the best safeguards against accidents are to keep ever mindful of the potential dangers and to always use good common sense. In the interest of safety, some general precautions are presented below — keep these in mind!

⚠WARNING

MOVING PARTS! Keep hands, hair, necktie, loose clothing, and test leads well away from moving parts, as serious injury could result from entanglement. Never run generator set with guards, covers, or screens removed.

⚠WARNING

HIGH VOLTAGE! Remember that the function of a generator set is to produce electricity and wherever electrical energy is present, there is the potential danger of electrocution. Keep everyone, especially children, away from the set while it is running and take precautions to prevent unqualified personnel from tampering with or attempting to operate your generator set. Have the set and electrical circuits serviced only by qualified technicians. Wiring should be inspected frequently — replace leads that are frayed or in poor condition. Do not operate electrical equipment when standing in water, on wet ground, or when your hands are wet.

⚠WARNING

LETHAL EXHAUST GAS! The engine powering your generator discharges deadly carbon monoxide as part of the exhaust gas when operating. Carbon monoxide is particularly dangerous in that it is odorless and colorless. Keep in mind that it can cause death if inhaled for even a short period of time. Never operate the generator set inside a building unless the exhaust gas is piped safely outside. Never operate in any area where exhaust gas could accumulate and seep back inside an occupied building. Avoid breathing exhaust fumes when working on or near the generator set.

⚠WARNING

DANGEROUS FUELS! Use extreme caution when handling, storing and using fuels. All fuels are highly explosive in a vapor state. Store fuel in a well-ventilated area away from spark producing equipment and out of the reach of children. Never add fuel to the tank while the engine is running to prevent spilled fuel from igniting on contact with hot parts or from ignition spark. Keep fuel lines and connections tight and in good condition — don't replace flexible fuel lines with rigid lines. Flexible sections are used to avoid breakage due to vibration. Additional precautions should be taken when using the following fuels:

Gasoline: Store gasoline only in approved red containers clearly marked GASOLINE. Don't store gasoline in any occupied building.

Propane (LP): Adequate ventilation is mandatory. Propane is heavier than air; install gas detectors low in room. Inspect detectors often.

Natural Gas: Adequate ventilation is mandatory. Natural gas rises; install gas detectors high in room. Inspect detectors often.

⚠WARNING

UNIT STARTS WITHOUT NOTICE! Units with Automatic Transfer Switches start automatically. Potential injury or electrocution can result. Turn Generator Master Switch on controller to OFF position, and remove battery cables (remove negative lead first and reconnect it last) to disable generator set before working on any equipment connected to generator.

⚠WARNING

EXPLOSIVE BATTERY GASES! The gases generated by a battery being charged are highly explosive. Do not smoke or permit flame or spark to occur near a battery at any time, particularly when it is being charged. Avoid contacting terminals with tools, etc., to prevent burns and to prevent sparks that could cause an explosion. Remove wristwatch, rings, and any other jewelry before handling battery. Any compartment containing batteries should be well ventilated to prevent accumulation of explosive gases. To avoid sparks, do not disturb battery charger connections while battery is being charged and always turn charger off before disconnecting.

⚠WARNING

EXCESSIVE NOISE! Never operate without adequate muffler or with faulty exhaust system — exposure to excessive noise is not only tiring but can lead to impairment of hearing.

⚠WARNING

DANGEROUS ACID! Avoid contact with battery electrolyte. It contains acid which can eat holes in clothing, burn skin, and cause permanent damage to eyes. Always wear splash-proof safety goggles when working around the battery. If battery electrolyte is splashed in the eyes or on skin, immediately flush the affected area for 15 minutes with large quantities of clean water. In the case of eye contact, seek immediate medical aid. Never add acid to a battery once the battery has been placed in service. Doing so may result in dangerous spattering of electrolyte.

⚠WARNING

ELECTRICAL SHOCK! Battery can cause electrical burns and shocks. Exercise reasonable care when working near the battery to avoid electrical connections through tools. Remove wristwatch, rings, and any other jewelry.

⚠WARNING

HOT COOLANT! Engine coolant is pressurized and hot enough to cause severe burns. If generator set is equipped with a coolant recovery tank, check coolant level at tank. If necessary to check coolant level at radiator or surge tank (on city water or remove radiator-cooled sets), place a rag over the cap and turn slowly to release pressure, before removing cap.

⚠WARNING

FLASH FIRE! To avoid the possibility of a flash fire, do not smoke or permit flame or spark to occur near carburetor, fuel line, fuel filter, fuel pump, or other potential sources of spilled fuel or fuel vapors.

⚠WARNING

EXPLOSIVE GASES! Remove AC power plug from outlet or turn off AC supply before connecting or disconnecting charger clips to battery terminals to avoid sparks igniting explosive battery gases.

⚠WARNING

UNINTENTIONAL STARTING! To prevent remote starting, place Generator Master Switch on controller to OFF position, and remove battery cables (negative lead first and reconnect it last) to disable generator set before working on any equipment connected to generator.

⚠WARNING

FIRE OR EXPLOSION! Transfer tanks with electrical pumps are designed for use with *diesel fuel only.* Fire or explosion may result from using them with gasoline or other volatile fuels.

⚠WARNING

DANGER OF ELECTROCUTION! When the generator is used for standby power, use of an automatic transfer switch is required to prevent inadvertent interconnection of standby and other sources of power. In some states and/or localities it is illegal to operate a standby generator without an automatic transfer switch. Failure to install an automatic transfer switch will cause "backfeed" into utility transmission lines and can cause serious injury or death.

⚠WARNING

FIRE HAZARD! Exhaust system components get extremely hot during operation and may ignite adjacent combustible materials. Keep exhaust piping well away from fuel lines, fuel tank and combustible materials. A double-sleeved thimble (shield) should always be installed where exhaust piping passes through a combustible wall or roof.

Location and Support

Locating Factors

Location is the key to a proper installation. The following sections will deal with the factors to consider in a proper installation. Before final plans are made for locating a generator set, the following questions should be raised concerning the set and the proposed site.

1. Is the structure strong enough to support the set and related equipment such as fuel storage tanks, batteries and radiators?
2. Can vibration be effectively isolated and dampened to reduce noise and prevent damage?
3. Is the area clean, dry and not subject to flooding?
4. Is the area large enough to provide easy access for servicing and repair?
5. Can adequate ventilation be attained in the area with a minimum amount of ductwork?
6. Can exhaust gases be expelled safely out of and away from the structure and other buildings?
7. Will an adequate supply of fuel be available to sustain operation during emergencies?
8. Will fuel tank location exceed the vertical lift capabilities of the fuel pump?

Weight

The weight of the generator set will determine the type of construction at the site. Most sets are mounted on concrete at ground level. Some, however, are located on upper levels of some other steel, concrete or wood construction.

The set's weight will determine how strong this construction should be, and can be found in the Specification Sheet for your particular model. Be sure that the weight of accessory items is added to the total requirements. This is especially important in upper story or roof installations.

Vibration

A certain amount of vibration is normal to the operation of any generator set. If severe vibration is transmitted to surrounding areas, structural damage may result.

To isolate vibration, Kohler Fast-Response sets are equipped with Vibro Mounts between Engine-Generator and steel mounting base. Kohler Co. does not recommend additional spring-type mounts between steel mounting base and mounting surface on these models. If additional mounts are used, they should be installed directly under the standard Kohler supplied mounts.

Sets larger than 400 kW do not include Vibro Mounts as standard equipment; Vibro Mounts are recommended between the steel mounting base and the mounting surface using the pre-drilled holes in the base. Vibro Mounts (Figure 2) are available for all Kohler generator sets.

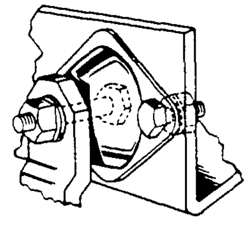


Figure 2. Vibro Mount

All fuel, coolant, exhaust, electrical connections, and cooling ductwork must have flexible sections so that vibration is not transmitted along these lines. Leakage or shorting can develop very quickly with rigid lines, plus there is the danger of eventual breakage due to fatigue if vibration goes unchecked.

Mounting Surface

A poured concrete surface provides the best foundation for a generator set. Whenever possible, the mounting surface should be separate and independent of the surrounding structure. If this is done, the set retains stability if the surrounding floor shifts or settles. This is especially important with larger sets where the weight alone could stress and crack flooring if not isolated. For smaller sets which may not require pre-engineered or specifically prepared surfaces, it is advisable to isolate the surface by cutting the concrete. All generator sets should be anchored to concrete with bolts buried in the surface as shown in Figure 3.

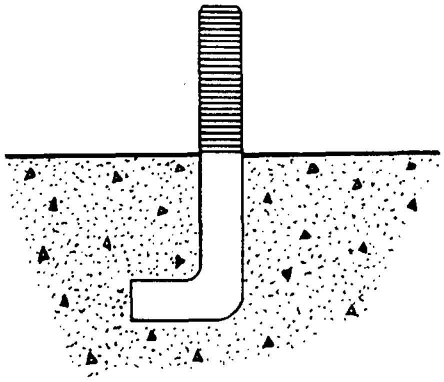


Figure 3. Anchor Bolts in Cement

Single pedestal or double pedestal surfaces or mounting blocks are often used. The single pedestal type (shown in Figure 4) is easiest to construct; however, the double pedestal type offers the advantage of easier cleaning and servicing under the set (Figure 4). The raised mounting block should be at least 6" (15.2 cm) wider, 6" (15.2 cm)

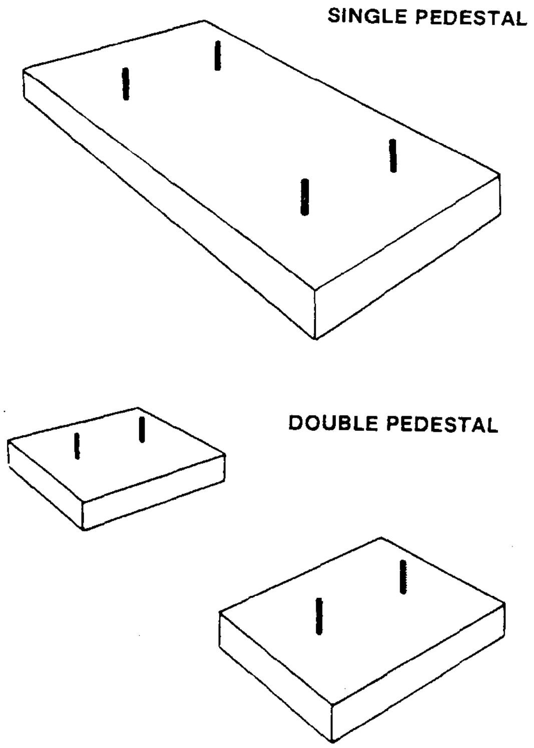


Figure 4. Typical Mounting Surfaces

longer at front, and 18" (45.7 cm) longer at the rear than the generator set frame. The extended area facilitates servicing of the set. An extension of 18" (45.7 cm) at either side of the set provides convenient location for battery boxes. See Figure 5.

⚠WARNING

EXPLOSIVE BATTERY GASES! The gases generated by a battery being charged are highly explosive. Do not smoke or permit flame or spark to occur near a battery at any time, particularly when it is being charged. Avoid contacting terminals with tools, etc., to prevent burns and to prevent sparks that could cause an explosion. Remove wristwatch, rings, and any other jewelry before handling battery. Any compartment containing batteries should be well ventilated to prevent accumulation of explosive gases. To avoid sparks, do not disturb battery charger connections while battery is being charged and always turn charger off before disconnecting.

While a concrete surface is preferable in most cases, there are times when this is not the most practical. If, for instance, the set is to be mounted on a wood floor, it may be best to mount it on steel beams. Heavy wood timbers may also serve the purpose. Remember that the type of installation will dictate the method.

The final determination of the location should be thought of as the best compromise of the many installation factors. By this we mean that all aspects of the installation should be evaluated and judged on their relative cost. The best method is that which will do the job safely and efficiently.

For example, it costs far less to run electrical conduit a distance of fifty feet (1,524 cm) than it does to run an air duct the same distance. Therefore, it makes sense to minimize the length of this duct at the expense of the conduit. Such evaluations should be made for every factor involved.

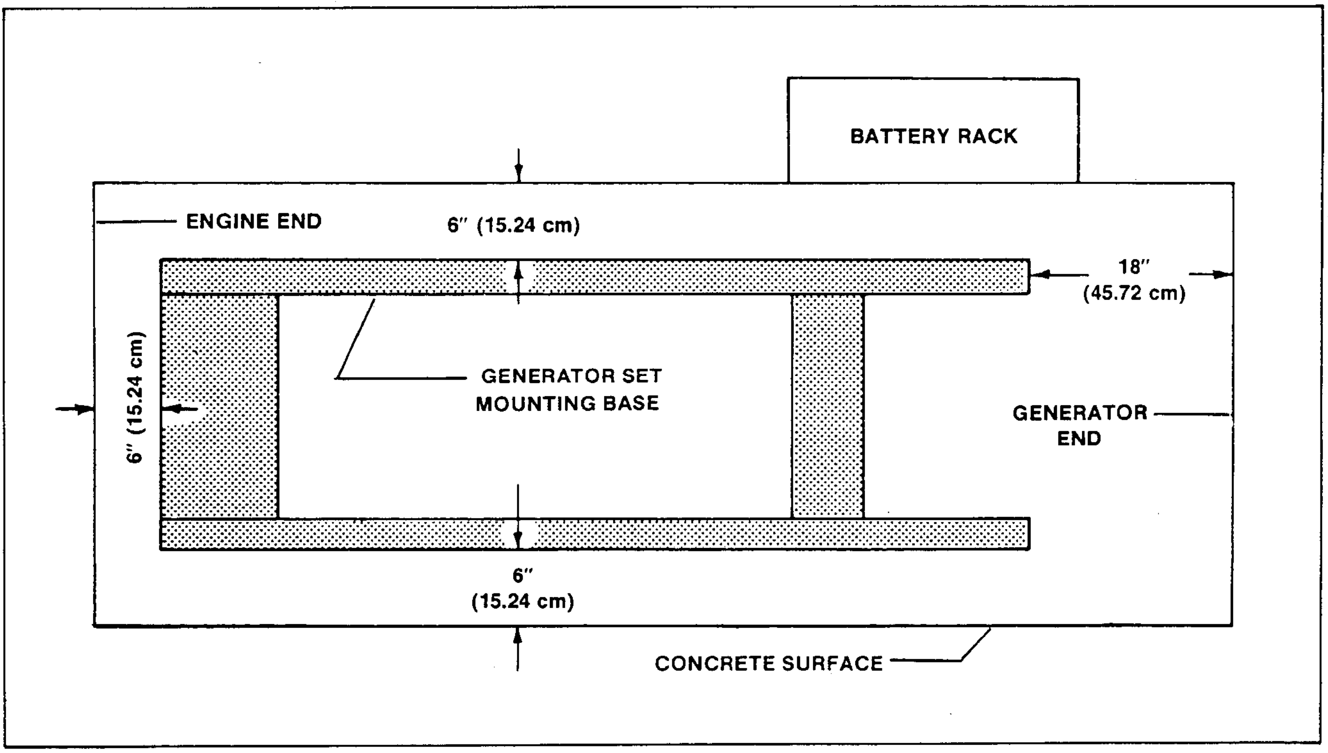


Figure 5. Mounting Surface Details

Air Requirements

General

An ample flow of clean, cool air is required to support combustion and dissipate heat. Approximately 70% of the heat value of fuel consumed by an engine will be rejected to the cooling medium and to the exhaust.

If a generator set is to be located in a building or enclosure, make certain that adequate air intake and air outlet openings are provided. If draft induced by the engine-generator cooling fan is not sufficient to prevent excessive temperatures, other means such as ductwork and/or ventilating fans will have to be used to provide adequate air flow.

In certain cold climate applications, controlled recirculation may be used as a means of heat recovery; however, special equipment such as thermostatically activated louvers and fans are needed to prevent engine and engine room overheating. Uncontrolled recirculation of heated air within an enclosure must be prevented. If this is allowed, the temperature in the enclosure quickly rises to the point where efficient cooling is no longer possible. With a properly designed ventilation system, sufficient temperature differential is not hard to maintain - even on the hottest days. Make certain air inlets and outlets cannot be blocked by snow and are kept clean and unobstructed at all times. The direction of the prevailing wind should be considered when positioning outlets. If wind velocity is considerable, it tends to cancel the effect of the radiator or exhaust fan. When strong prevailing winds are anticipated, face the air inlet into the wind and the outlet on the opposite or leeward side.

In many installations it may be desirable to install louvers in the inlet and outlet openings. Louvers may either be stationary or movable. In areas of great temperature variation, it is often best to install movable louvers which can be adjusted to regulate air flow. Louvers should be thermostatically operated to regulate room temperature. See Figures 6 and 7.

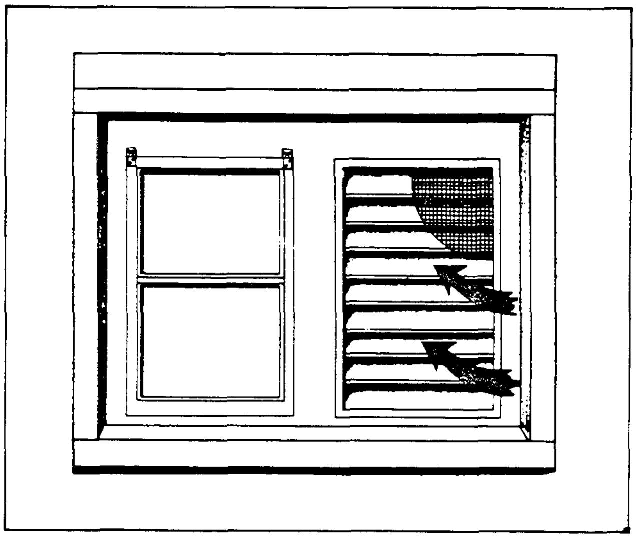


Figure 6. Fixed Louvers for Air Inlet

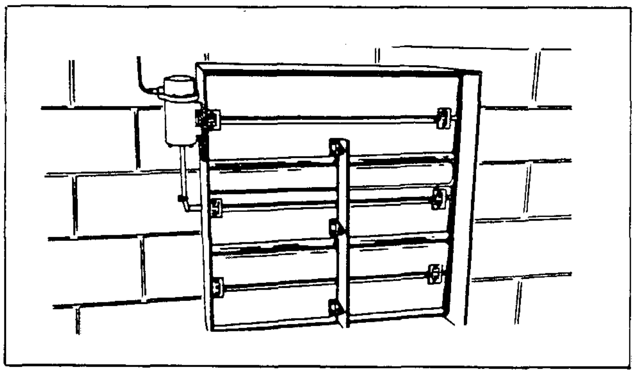


Figure 7. Thermostatically Controlled Louvers

Louvers, however, restrict air flow and the size of the opening must be increased to compensate for loss of air volume. If the atmosphere in which the set is to be installed is highly contaminated with impurities such as dust, chaff, etc., it may be necessary to install a filter in the inlet opening. Furnace type filters have been very satisfactory. Here, again, a certain amount of air flow is lost which must be compensated for by at least doubling the size of the opening.

If an exhaust fan is used, (Figures 8 and 9) check the fan's capacity in cubic feet (meters cubed) per minute. Follow the fan manufacturer's recommendations to determine the size of the inlet and outlet openings.

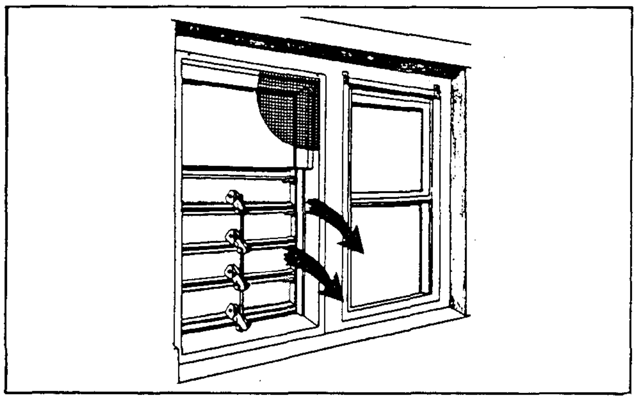


Figure 8. Exhaust Fan Operated Louvers

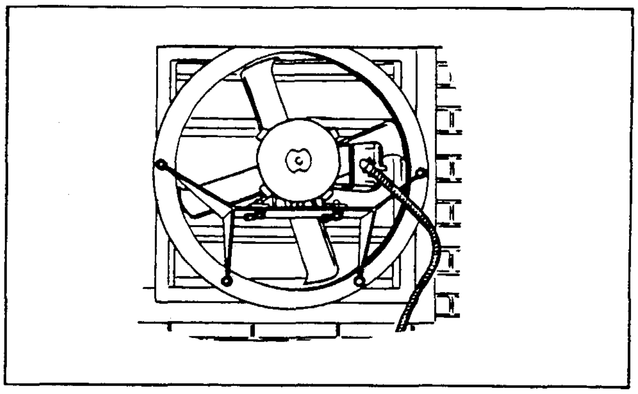


Figure 9. Fans Required on Some Installations

The following are minimum air inlet and outlet recommendations:

1. If LOUVERS are used the size of the opening should be increased approximately 50%.
2. If WINDOW SCREENING is used the opening should be increased approximately 80%.
3. If FURNACE FILTERS are used, the opening should be increased 120%.

Kohler air-cooled generator sets are powered by gasoline, gas or diesel engines. The three basic types of air cooling systems are discussed separately on the following pages. To obtain the required volume of air in the compartment or enclosure, air inlet and outlet openings must be at least one square foot (.092 m^2) for sets 2 kW and smaller. For larger sets determine inlet and outlet size on the basis of .25 square feet (.023 m^2) for each 1000 watts of capacity. A 5000 watt set would, for example, require inlets and outlets of 1.25 square feet (.115 m^2) ,each.25 x 5 = 1.25 (.023 m^2 x 5 = .115 m^2). Air circulation requirements are listed in each model's Specification Sheet. Remember to increase size of openings for louvers, screens, filters, etc.

FORCED AIR:

With the forced air system, cooling air is drawn in through the front of the engine, circulated around finned areas of the cylinder block and head, then ejected toward the rear or generator end of the set. This system is best suited to wide-open, well ventilated areas. It is not recommended for confined areas unless intake and/or exhaust fans can be used to achieve the required air circulation. See Figure 10.

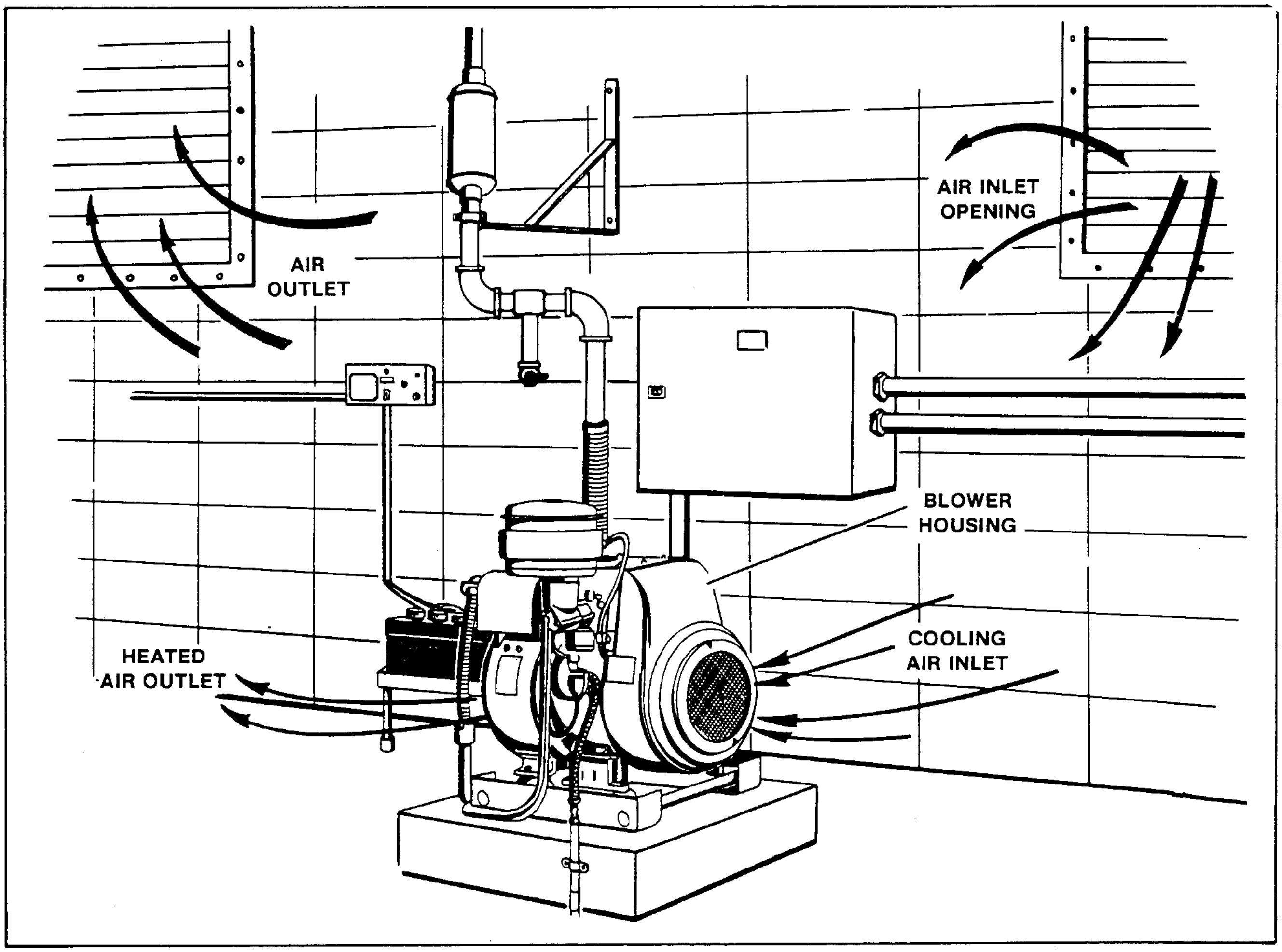


Figure 10. Standard Forced Air Cooling System

AIR VAC:

The direction of air flow with the Air Vac system is opposite that of the conventional forced air cooling system. This system can be used in confined areas since the reverse flow necessitates use of a blower scroll which is easily connected to ductwork. For duct dimensions refer to Table 3 in the "Application Data" section at the back of this manual. With Air Vac, cooling air is drawn across the generator end of the unit, into the finned areas then out into the scroll which is located at the front of the engine. The heated air can then be forced through ductwork to outlet outside the building. See Figure 11.

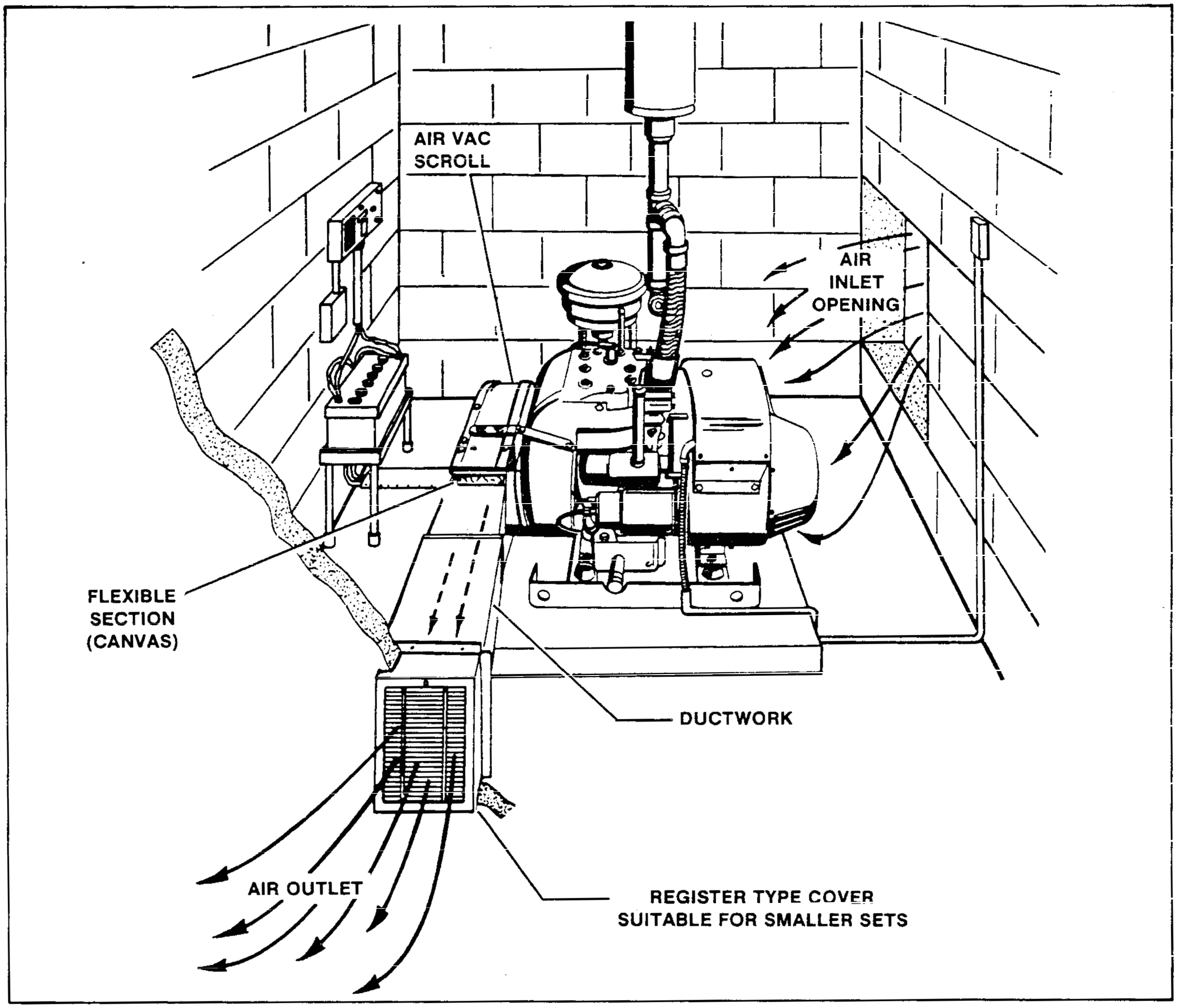


Figure 11. Air Vac Cooling System

AIR VENT:

This system is used on the air-cooled Diesel and some gas-gasoline models. It includes special ductwork which directs the flow of heated air to outlet at the top or side of the engine. With air vent system, flow of air is not reversed as it is with the Air Vac system. The Diesel models using air vents all outlet to the side while gas-gasoline models use either a top outlet or side outlet arrangement. Additional ductwork is usually connected to the engine ductwork to carry the heated air outside. For duct dimensions refer to Table 3 in the "Application Data" section at the back of this manual. This system is also efficient in maintaining consistent operating temperatures in confined areas. See Figure 12.

NOTE

Air vac cooling system should be ordered factory installed on gas-gasoline models since major components of the engine are affected. Air vent requires very little engine modification making it adaptable for field installation.

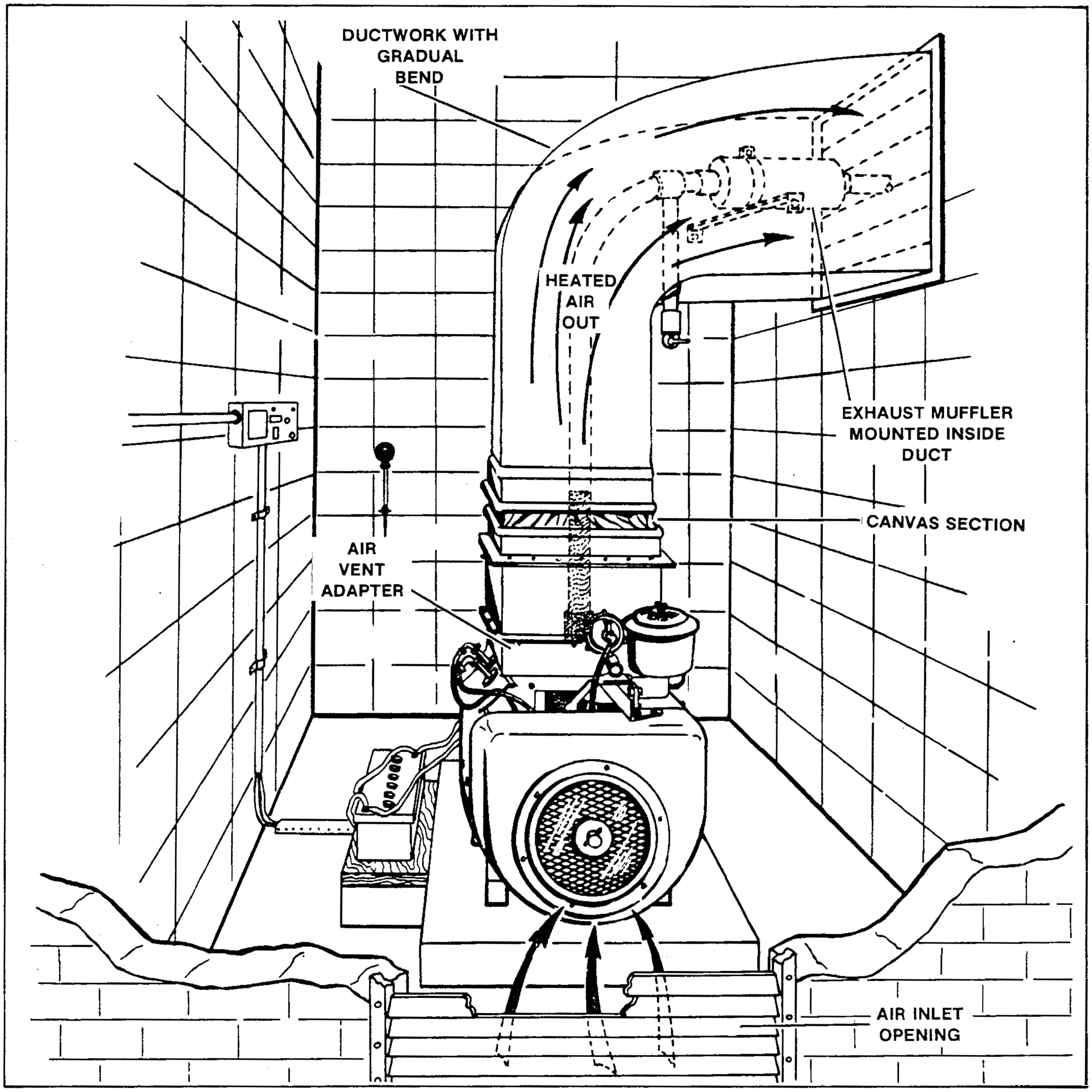


Figure 12. Air Vent System on Air-Cooled Set

Liquid Cooled Models

Three liquid cooling systems are used with Kohler Generator Sets. Each system must be reviewed separately since certain requirements pertain to specific systems.

⚠WARNING

HOT COOLANT! Engine coolant is pressurized and hot enough to cause severe burns. If generator set is equipped with a coolant recovery tank, check coolant level at tank. If necessary to check coolant level at radiator-cooled sets, place a rag over the cap and turn slowly to release pressure, before removing cap.

RADIATOR COOLING:

All radiator equipped generator sets have pusher (blower) type fans, which draw cooling air across the rear or generator end of the unit, then through the radiator from the engine side.

Wherever possible, the radiator should be positioned so that the heated air will blast directly and horizontally into the air outlet of the room or enclosure. Use ductwork from the radiator to the outlet to avoid recirculation of heated air.

Sheet metal ductwork must be self-supported with a flexible section of heavy canvas or similar material (to prevent vibration transmission from engine to ductwork) installed close to the radiator. See Figure 13. A radiator fan moves a large volume of air, and creates a definite amount of noise. Consider this factor when positioning the outlet as sound can be amplified if the outlet is placed too close to adjacent buildings.

The prevailing wind direction should also be considered and compensated for when placing air inlets and outlets. If strong, constantly shifting winds are common, a wind wall may be necessary to deflect them.

An opening one and one-half times the size of the radiator air duct frame should be used to discharge heated air.

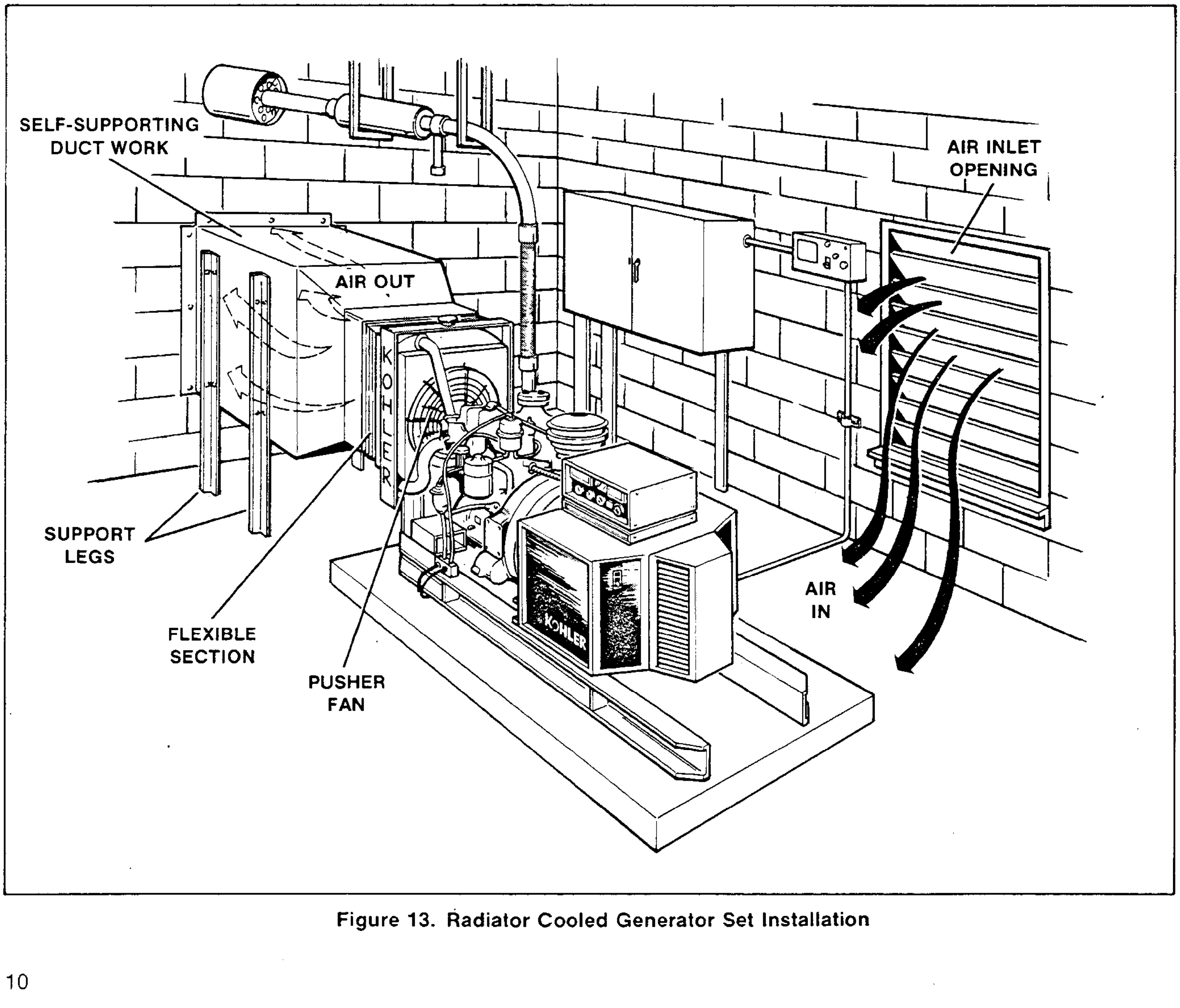


Figure 13. Radiator Cooled Generator Set Installation

Ductwork from frame to the outlet opening is recommended especially on the larger sets. The cooling air inlet opening must be at least as large and preferably 50% larger than the outlet. Static pressure in the radiator air duct must never exceed .5 inches (12.7 mm) of water. Inlet and outlet openings must be increased in size to allow for any restrictions such as louvers. Air requirements and air duct dimensions for radiator cooled sets are listed in Table 4 in the "Application Data" section at the back of this manual.

REMOTE RADIATORS:

With the radiator mounted in a remote area, the generator set can be located in a confined area or, for example, a subground location where it is impossible to construct air inlets and outlets of adequate size for the radiator. Often, the engine driven water pump is capable of providing sufficient circulation to the remote radiator. If, however, line distance or restriction results in a pressure drop of more than 2 psi (0.141 Kg/cm²), an auxiliary pump must be used. If the radiator is mounted more than 21 feet (640 cm) above the engine water pump, a hot well should be added to the system to prevent seals and gaskets from leaking due to excessive "head" pressures. See Figure 14. A hot well at the engine level is divided into two compartments - a hot side and a cold side. Heated water is forced by the engine pump into the "hot" side and is then drawn off by the auxiliary pump and forced into the radiator. After circulating through the radiator, coolant flows back to the cold side of the well where it is drawn off by the engine water pump. Head pressures are thus confined to the hot well, and the coolant circulates through the engine at normal pressures. Pressure can also be isolated by installing a heat exchanger between the engine and the remote radiator. Remote radiator specifications are listed in Table 5 in the "Application Data" section at the back of this manual.

The top of the remote radiator must be the highest point in the system to function properly. The fan motor is connected to generator output and will run when the generator set is operating.

With the radiator at a remote location, it is easily overlooked each time the generator set is serviced. For this reason, low-water alarms or automatic "make-up" controls are often included in these systems. Antifreeze is required if the radiator is subject to freezing temperatures.

To determine radiator size and air requirements check the Specification Sheet for your model and refer to the remote radiator specifications chart in the "Application Data" section at the back of this manual. The amount of air required to ventilate the generator set room or enclosure determines the size of the air inlet and outlet - a ventilating fan is usually necessary as generator heat losses as well as engine heat losses must be dissipated.

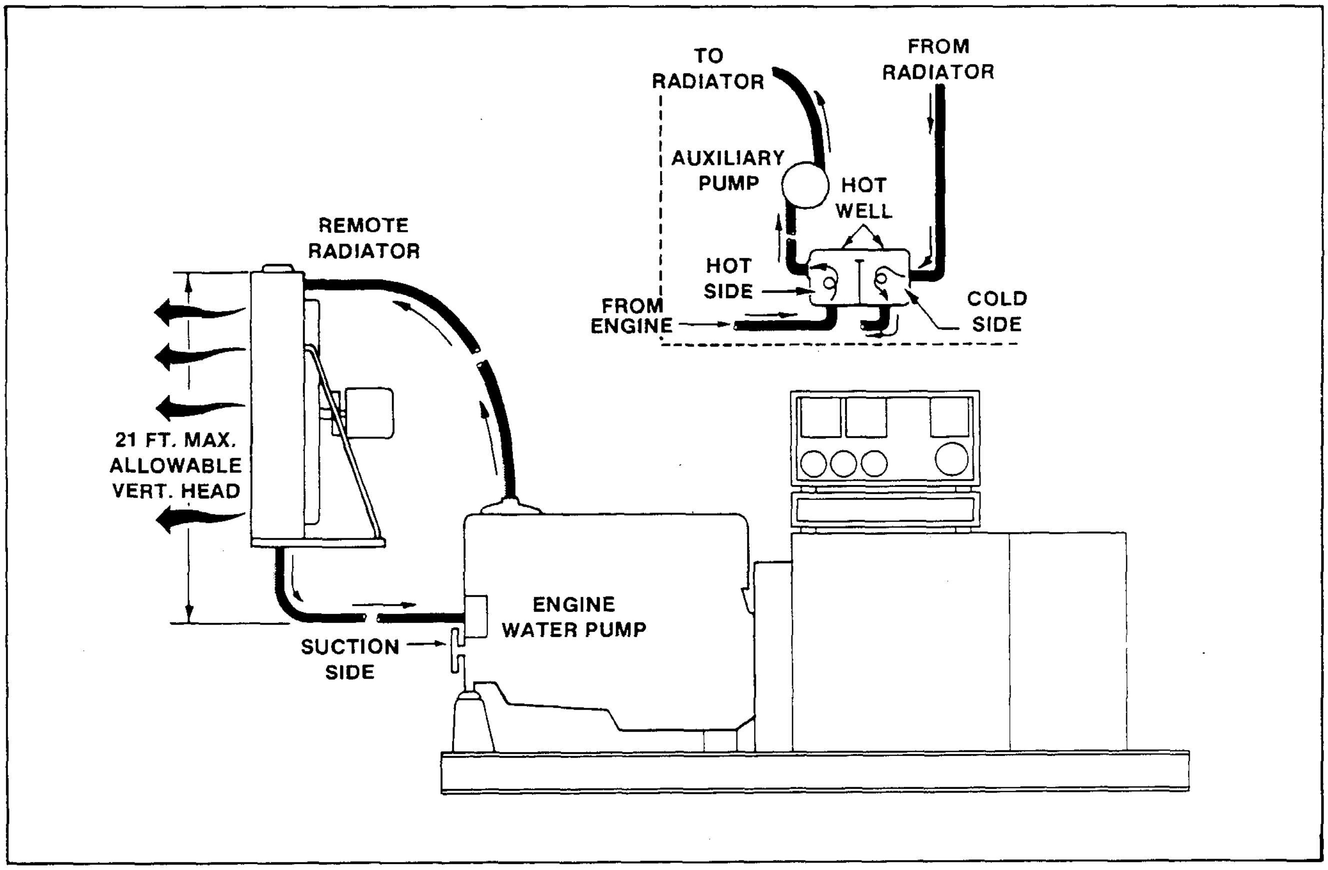


Figure 14. Schematic Diagram of Remote Radiator System

CITY WATER COOLING:

This system utilizes city water for cooling. See Figure 15. In this system, a shell and tube type heat exchanger is used to provide more uniform control of engine operating temperatures. Jacket water from the engine water pump circulates through the engine and surge tank, then into the heat exchanger and back into the water jacket. As heated engine water circulates around tubes in the exchanger, "raw" cooling water from the city is circulated through the separate tubes within the exchanger. The city system absorbs the heat and this heated water is forced away into a sewer drain.

NOTE

> These city water type heat exchangers are not suitable for use with remote radiators as they are sized for a lower incoming water temperature than provided by a remote radiator.

Water inlet and outlet connections are mounted on generator set skid and isolated from engine vibration by flexible sections. If generator set is vibro-mounted to skid and skid is bolted directly to mounting base, no additional flexible sections are needed between connection points on skid and city lines. If generator set skid is mounted to base with vibration isolators, flexible sections must be used between connection points on skid and city lines.

A solenoid valve mounted at inlet connection point automatically opens upon start-up of generator set making water under pressure from city mains available for engine cooling. This valve automatically closes when the unit shuts down. If a flexible section is used between the inlet connection on the steel mounting base and the city water supply, the solenoid valve must be moved from the skid to between the flexible section and the city water supply. An additional customer supplied valve may be used ahead of the entire system to manually shut off city water when servicing the set.

CAUTION

> A loose or broken flexible section may result in flooding of generator set enclosure. Locate solenoid valve ahead of any flexible section in city water supply line. A broken water line would cause engine to overheat shutting down generator set and closing solenoid valve.

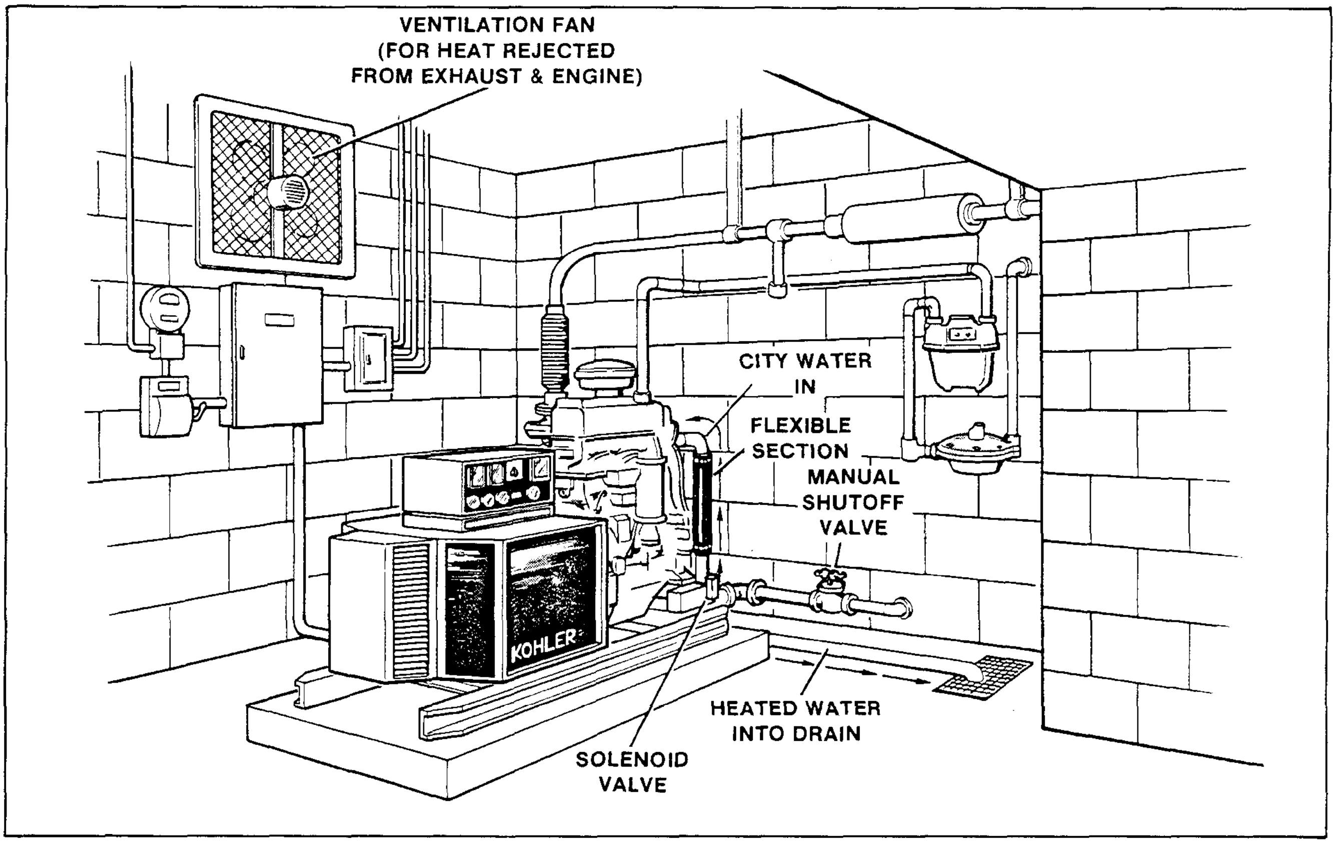


Figure 15. Installation Using City Water Cooling System

COOLING TOWER:

Cooling tower systems are used in certain arid climates. See Figure 16. The typical evaporative cooling tower system employs two separate systems for cooling. The engine system usually includes the engine water pump, a heat exchanger, a surge tank and the water jacket of the engine. The raw water system consists of the cooling tower, a raw water pump and the tube portion of the heat exchanger. Raw water is circulated through the heat exchanger tubes to absorb heat from the engine system which is circulated around the surrounding shell of the exchanger. The heated raw water is directed into a pipe at the top of the cooling tower and sprayed down into the tower.

The construction of the typical tower is such that outside air can circulate through the spray, cooling the raw water. A small amount of raw water is lost to evaporization but most collects at the bottom of the tower and is recirculated through the raw water system. Because of evaporization, "make-up" water provisions must be made.

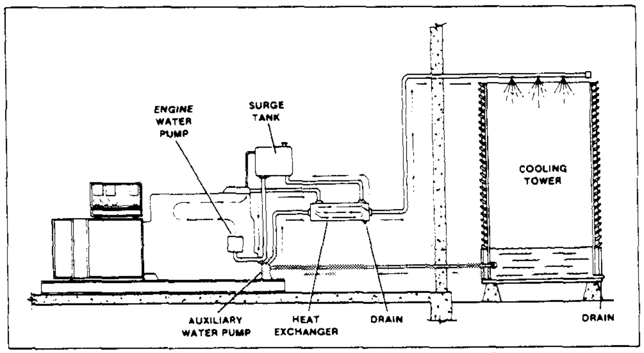


Figure 16. Schematic of Cooling Tower System

BLOCK HEATERS:

Block heaters are recommended on all standby applications where the set is subject to temperatures below 60° F (16° C) and are available as installed accessories on all Kohler Generator Sets. The block heater should be connected to some single phase source of power, either 120, 208 or 240 volt, depending on the particular heater. The block heater required for each model is listed in the individual Specification Sheets.

CAUTION

Overtightening of block heater fastener(s) can result in coolant leakage and possible damage to block heater.

CAUTION

BLOCK HEATER DAMAGE! Do not energize block heater until engine block is filled with coolant and the generator set is run to remove trapped air. Otherwise, block heater failure will result. Unplug block heater prior to draining cooling system.

Test run the generator set for a few minutes and check for leaks.

NOTE

Special attention should be given when checking for proper coolant level. After a radiator has been drained, it normally requires some time before complete refill of all air cavities takes place.

RECOMMENDED COOLANT:

Fill cooling system to proper level with fresh coolant. This must be performed prior to startup of generator set and energizing block heater(s).

A solution of 50% ethylene glycol and 50% clean, softened water is recommended to inhibit rust/corrosion and to provide freezing protection to −34°F (−37°C). Use engine manufacturer's recommendations when available.

The following is recommended to prevent air pockets from forming while filling engine block with coolant:

a. Open air bleed valve (if so equipped) on top of engine block. Be sure to close before starting engine.

b. Add coolant no faster than two U.S. gallons (7.6 L) per minute. Allow time for air to be displaced.

c. Close all coolant drains, petcocks, air bleed valves, etc. Check that the controller master switch is in the OFF position. Reconnect battery, negative lead last.

d. Start generator set and allow to run for about 10-15 minutes. STOP generator set and recheck coolant level. Repeat procedure, as necessary, until coolant can no longer be added.

⚠WARNING

HOT COOLANT! Allow engine to cool and release pressure from cooling system before checking the coolant level or installing the block heater kit. To release pressure, cover the radiator cap or surge tank cap in a thick cloth, then turn it slowly counterclockwise to the first stop. After the pressure has been completely released and the engine has cooled, remove cap.

NOTE

Special attention should be given when checking for proper coolant level. After a radiator has been drained, it normally requires some time before complete refill of all air cavities takes place.

Exhaust Requirements

While it is important to supply the proper amount of clean air to the cylinder, it is equally important to discharge the gases of combustion. If these gases remain in the cylinder, the next cycle cannot burn the fuel completely. This condition results from excessive back pressure which is caused by any one or combination of these conditions:

1. Exhaust pipe diameter too small for the length.
2. Exhaust pipe too long for the diameter.
3. Excessive number of sharp bends in exhaust system.
4. Inadequate muffler.
5. Incorrect construction of muffler resulting in high resistance.
6. Obstruction in exhaust system.

NOTE

Back pressure must not exceed engine manufacturers recommendations as shown on the Specification Sheet for each Model.

⚠WARNING

HOT PIPING! An engine gets hot whiel running and exhaust while system components get extremely hot. Do not work on generator set until unit is allowed to cool.

⚠WARNING

LETHAL EXHAUST GAS! The engine powering your generator discharges deadly carbon monoxide as part of the exhaust gas when operating. Carbon monoxide is particularly dangerous in that it is odorless and colorless. Keep in mind that it can cause death if inhaled for even a short period of time. Never operate the generator set inside a building unless the exhaust gas is piped safely outside. Never operate in any area where exhaust gas could accumulate and seep back inside an occupied building. Avoid breathing exhaust fumes when working on or near the generator set.

Exhaust Piping

Exhaust lines should be as short and straight as possible. Extended runs and elbows tends to clog with carbon and resist the flow of gases. Each pipe fitting and elbow will hinder the exhaust flow. Refer to Table 1 in the "Application Data" section at the back of this manual for exhaust line recommendations.

Kohler offers a complete line of silencers, and steel and stainless steel flexible exhaust connectors. They are selected for their ability to withstand exhaust flow and temperature without creating excessive back pressure to the engine. The engine exhaust system must be correctly sized and installed if rated engine performance is to be realized. Contact your Kohler Generator Distributor for a list of available exhaust silencers.

NOTE

Never connect silencer directly to the manifold. A flexible section must be provided between exhaust manifold and exhaust line to prevent vibration transmission between engine and exhaust piping.

A short, solid section of pipe between 6" (15.24 cm) or 8" (20.32 cm) long should be placed between the connection of the manifold and the flexible coupling. This nipple will reduce the possibility of the hot gases burning up the flexible coupling.

Water, one of the by-products of combustion, will be present in the exhaust piping or silencer. This water must be kept from draining back into the engine. This can be done by slanting the horizontal section of the exhaust pipe downward slightly, away from the engine. A water trap consisting of a tee extension with a drain cock should be provided. See Figure 17 and 17a.

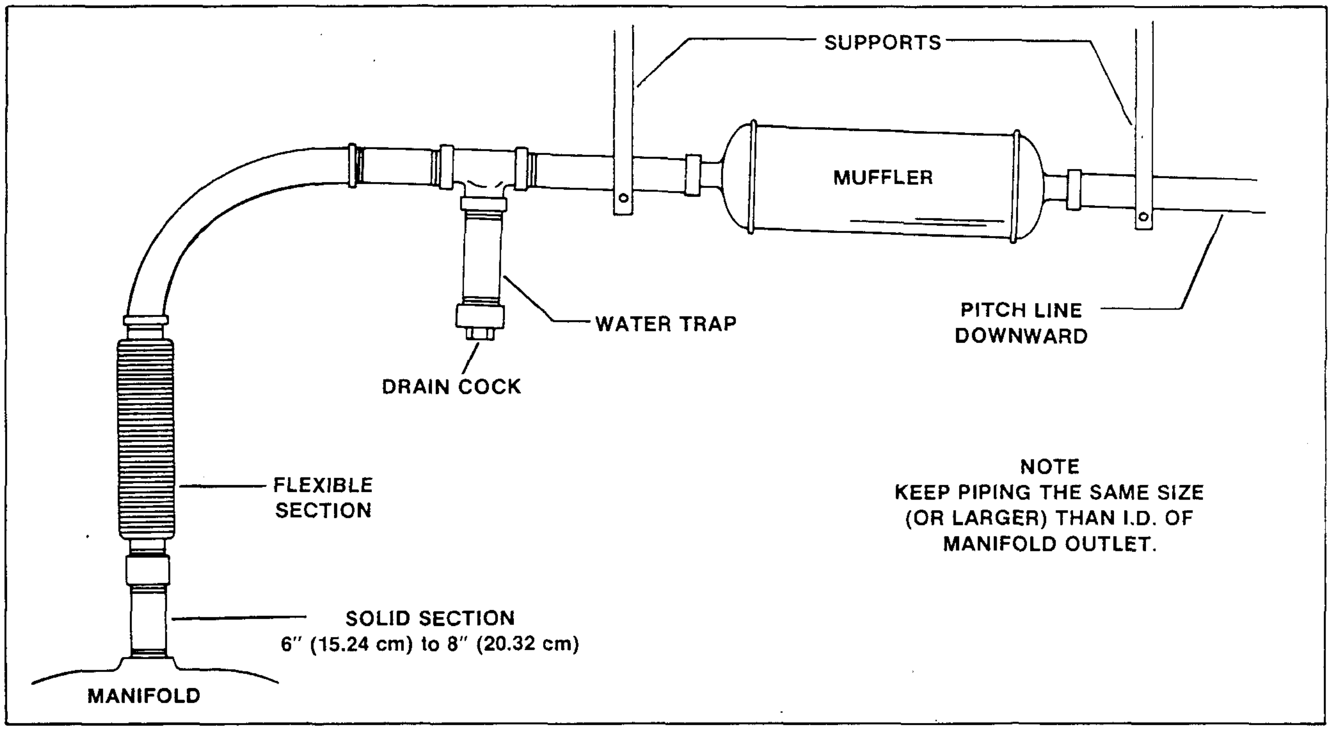


Figure 17. Schematic of Exhaust System with End Inlet Silencer

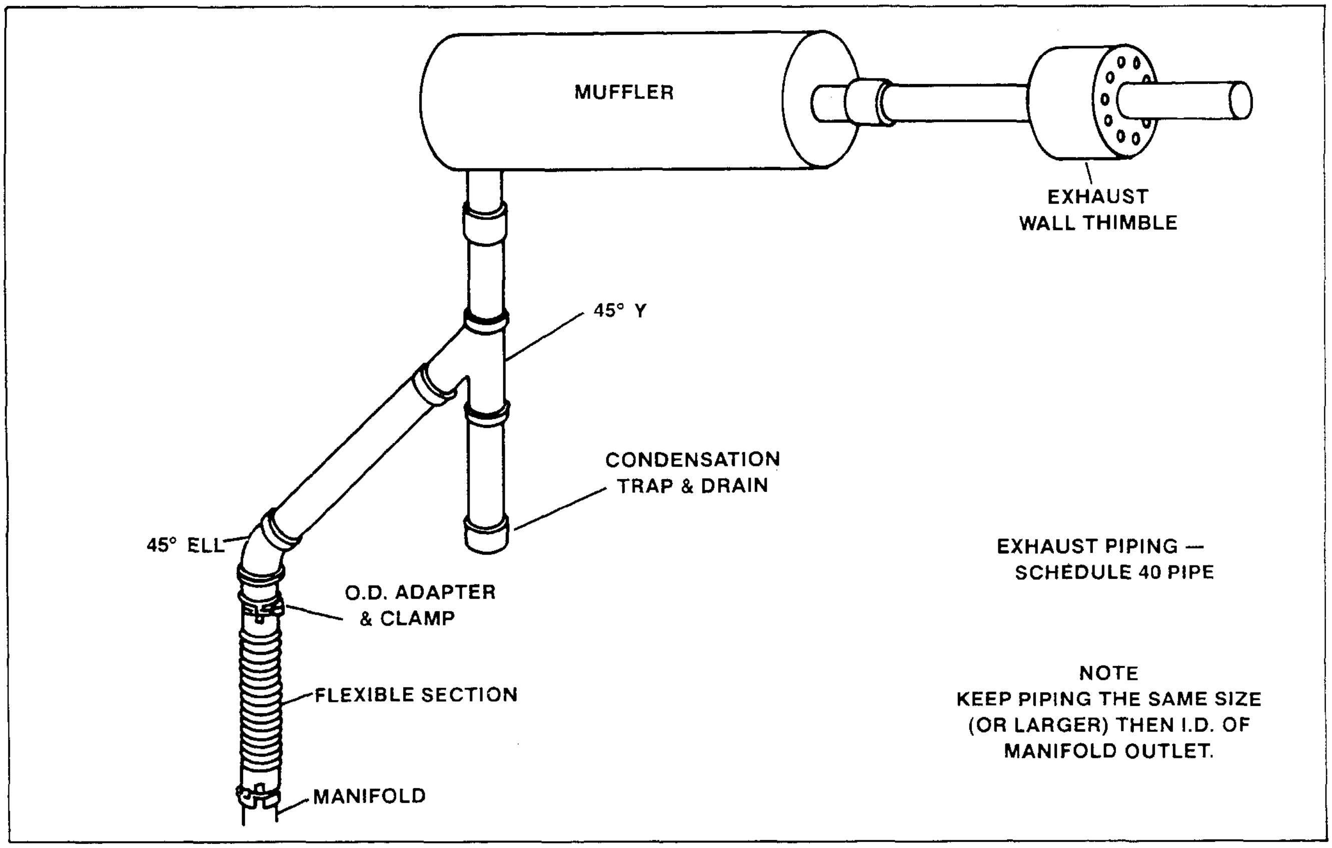


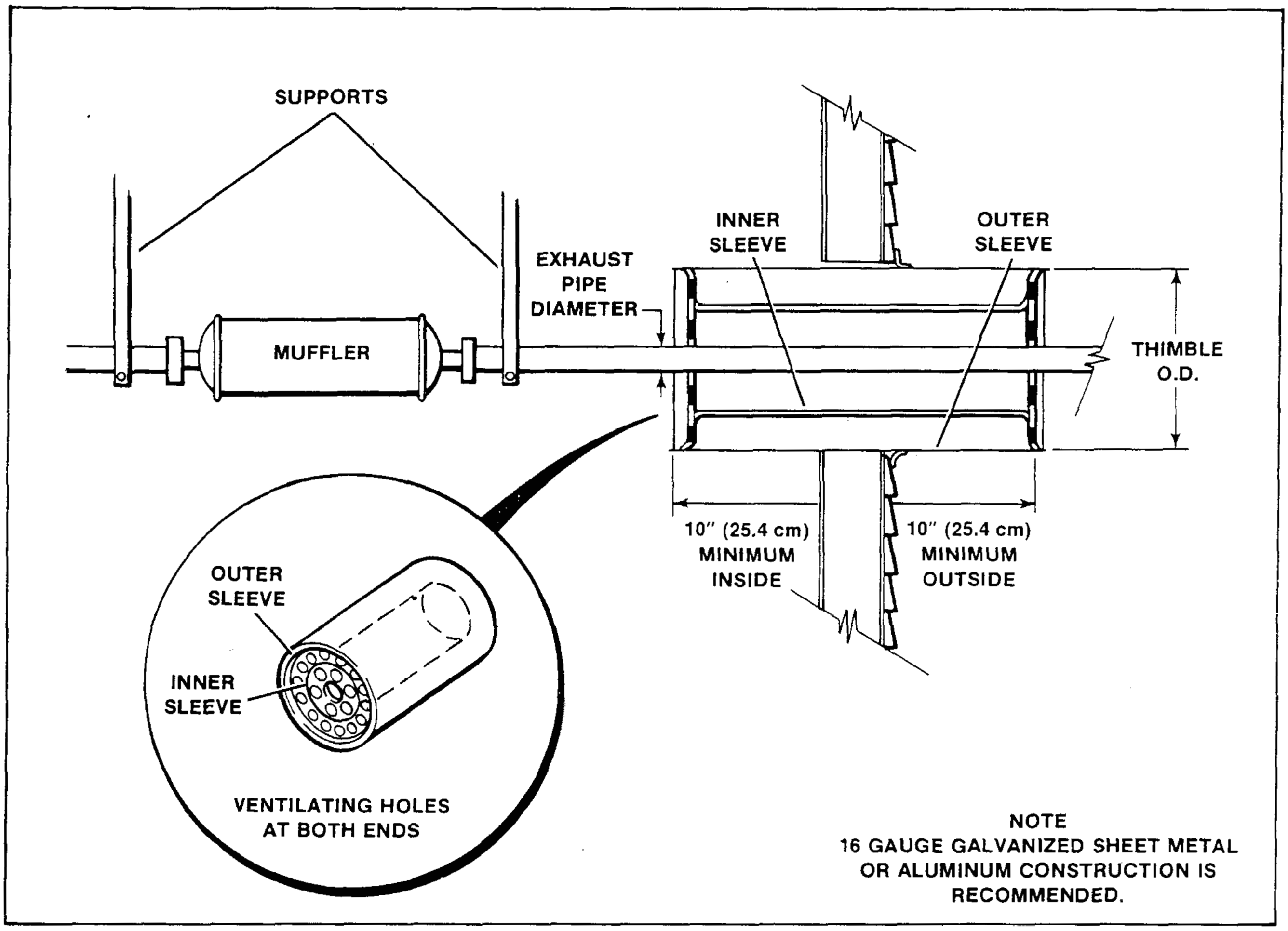
Figure 17a. Schematic of Exhaust System with Side Inlet Silencer

Exhaust Piping Through Walls and Roofs

Always check local and state laws pertaining to hot gas pipes before making plans for running exhaust piping through walls or roofs. If the exhaust pipe must pass through combustible walls or roofs, use an exhaust thimble to prevent exhaust pipe heat from being transmitted to the combustible material. Construction details of a typical through wall double sleeve thimble are shown in Figure 18. They are usually fabricated at local sheet metal shops to the specifications furnished by the installation engineer. The minimum thimble diameters for some common exhaust pipe sizes are listed in Table 2 of the "Application Data" section at the back of this manual.

⚠WARNING

FIRE HAZARD! Exhaust system components get extremely hot during operation and may ignite adjacent combustible materials. Keep exhaust piping well away from fuel lines, fuel tank and combustible materials. A double-sleeved thimble (shield) should always be installed where exhaust piping passes through a combustible wall or roof.



NOTE
16 GAUGE GALVANIZED SHEET METAL OR ALUMINUM CONSTRUCTION IS RECOMMENDED.

Figure 18. Double Thimble - Wall Outlet Details

The thimbles should be constructed so that they extend at least 10" (25.40 cm) both ways from the surface of the wall or roof. Holes are provided at both ends to allow cooling air to circulate through the thimble. If screening is used on the outer end to keep birds, rodents, etc., from entering the thimble, make sure that the mesh is large enough so that it doesn't impair air circulation through the thimble. If the exhaust pipe must exit through a roof, a rain shield must be included above the thimble as shown in Figure 19. The rain cap as shown on the end of the exhaust pipe is recommended only in areas not subject to freezing temperatures. In an area where freezing is common, extend the exhaust piping well beyond the roof and use a gradual "U" bend at the end to direct the exhaust outlet downward which will keep rain, snow, etc., out of the pipe.

⚠WARNING

FIRE HAZARD! Exhaust system components get extremely hot during operation and may ignite adjacent combustible materials. Keep exhaust piping well away from fuel lines, fuel tank and combustible materials. A double-sleeved thimble (shield) should always be installed where exhaust piping passes through a combustible wall or roof.

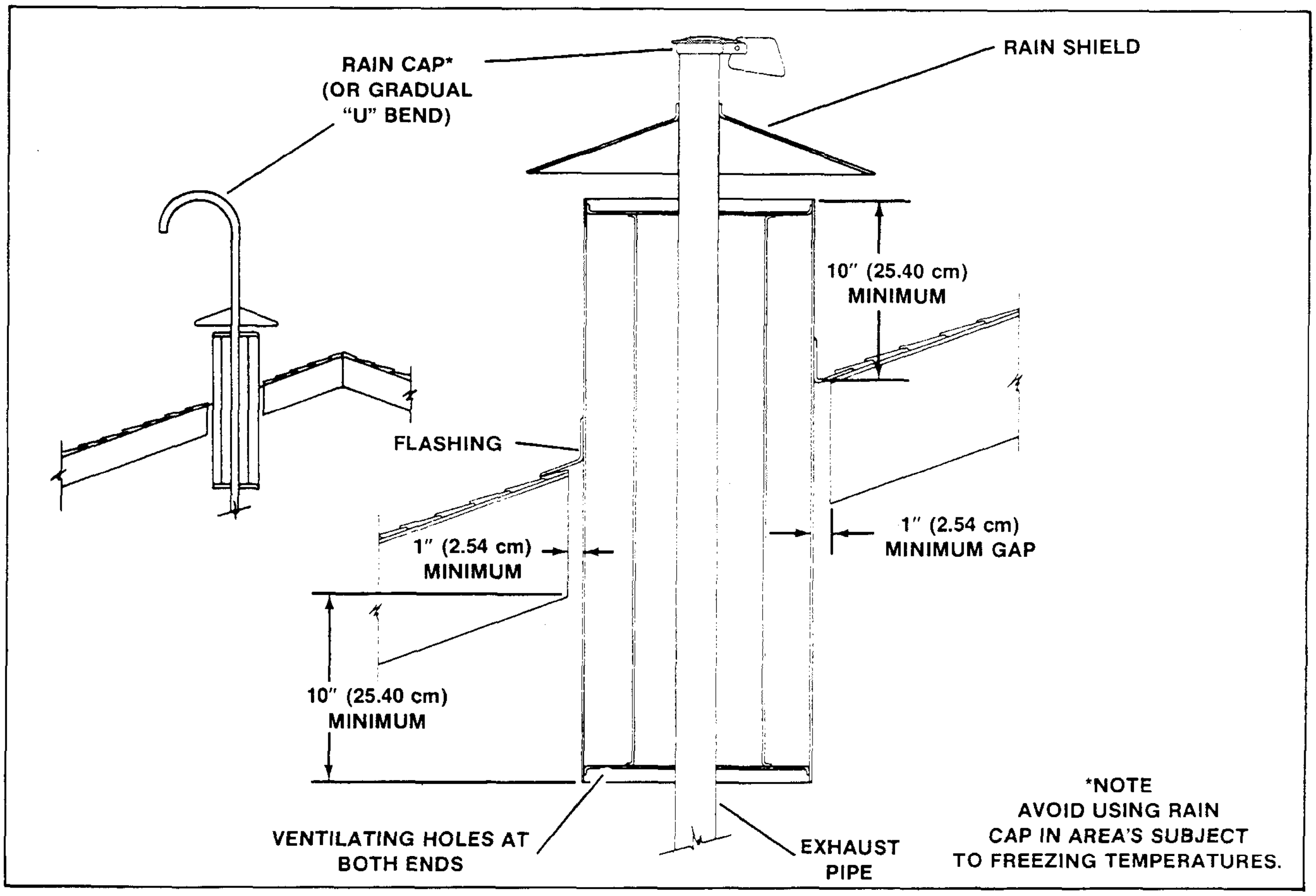


Figure 19. Double Thimble - Roof Outlet Details

Fuel Systems

When planning an installation, check local and state regulations regarding fuel storage and handling. Piping and fuel system components must conform to these regulations. If no such regulations exist, the National Fire Protection Association (NFPA) has established standards which can serve as a guide to good installation practices. These standards are published in booklet form and are available at Nominal cost from the National Fire Protection Association, 60 Battery March Street, Boston, Massachusetts, 02110. The installation engineer should obtain a copy of NFPA #37 which contains installation and operation standards for gas, gasoline and diesel fueled internal combustion engines. The other booklets referred to in NFPA #37 should be procured whenever applicable to the particular installation involved.

Since requirements vary according to the type of fuel used, each type is discussed separately. Gasoline, gas (gaseous) and diesel engines power Kohler Generator Sets.

⚠WARNING

DANGEROUS FUELS! Use extreme caution when handling, storing and using fuels. All fuels are highly explosive in a vapor state. Store fuel in a well-ventilated area away from spark producing equipment and out of the reach of children. Never add fuel to the tank while the engine is running to prevent spilled fuel from igniting on contact with hot parts or from ignition spark. Keep fuel lines and connections tight and in good condition — don't replace flexible fuel lines with rigid lines. Flexible sections are used to avoid breakage due to vibration. Additional precautions should be taken when using the following fuels:

Gasoline: Store gasoline only in approved red containers clearly marked GASOLINE. Don't store gasoline in any occupied building.

Propane (LP): Adequate ventilation is mandatory. Propane is heavier than air; install gas detectors low in room. Inspect detectors often.

Natural Gas: Adequate ventilation is mandatory. Natural gas rises; install gas detectors high in room. Inspect detectors often.

Gasoline

The availability of gasoline makes it an ideal fuel for many generator sets. Being a liquid fuel, it is relatively easy to handle and store. It is also easily ignited, which offers easy starting; however, this can also be considered a disadvantage as it necessitates special installation precautions. Gasoline readily changes to vapor state and vapor lock problems can occur if this is overlooked when planning the fuel system.

There are several basic gasoline fuel systems. The simplest system includes a small engine-mounted fuel tank and is limited to the smallest generator sets. (Gasoline tanks larger than 1 gallon (3.78 lt) capacity are usually not permitted inside a building.) On larger sets where the tank must be located outside an enclosure, but within lift capabilities of the engine fuel pump, the same basic arrangement can be used. This is shown schematically in Figure 20. The capabilities of engine operated fuel pumps vary in vertical lift from 5 to 8 feet (152 to 244 cm) and horizontally from 12 to 14 feet (366 to 427 cm). If these limits are exceeded, an electric auxiliary pump can be used to force fuel to the engine operated pump. The auxiliary pump should be located as close as possible to the main tank to push rather than pull the fuel, thus minimizing the chance of cavitation and vapor lock. The auxiliary pump must be wired to the starting controls of the set.

PRIMING TANKS:

On stand-by installations where automatic starting is necessary, a gravity-feed priming tank should be used. These tanks are limited in size - 1 quart (0.95 lt) capacity on most sets and 1 gallon (3.78 lt) capacity on the largest sets. They are intended only to aid starting. During nonoperating periods gasoline may evaporate from the carburetor, and fuel in the supply line may drain back to the main tank. This causes a delay in starting since fuel must be pumped the entire distance of the line before the engine can start.

With the priming tank arrangement as shown in Figure 21, gasoline is drawn out of the main tank by the fuel pump and delivered to the priming tank. The carburetor is supplied with fuel under gravity from the priming tank. While the set is operating, the fuel enters the priming tank under pressure from the fuel pump. For this reason, a separate fuel return line must be extended from the top of the priming tank back to the main tank to bleed off the overflow or excess of fuel. See Figure 22. The return line must be at least as large as the fuel inlet line to the priming tank.

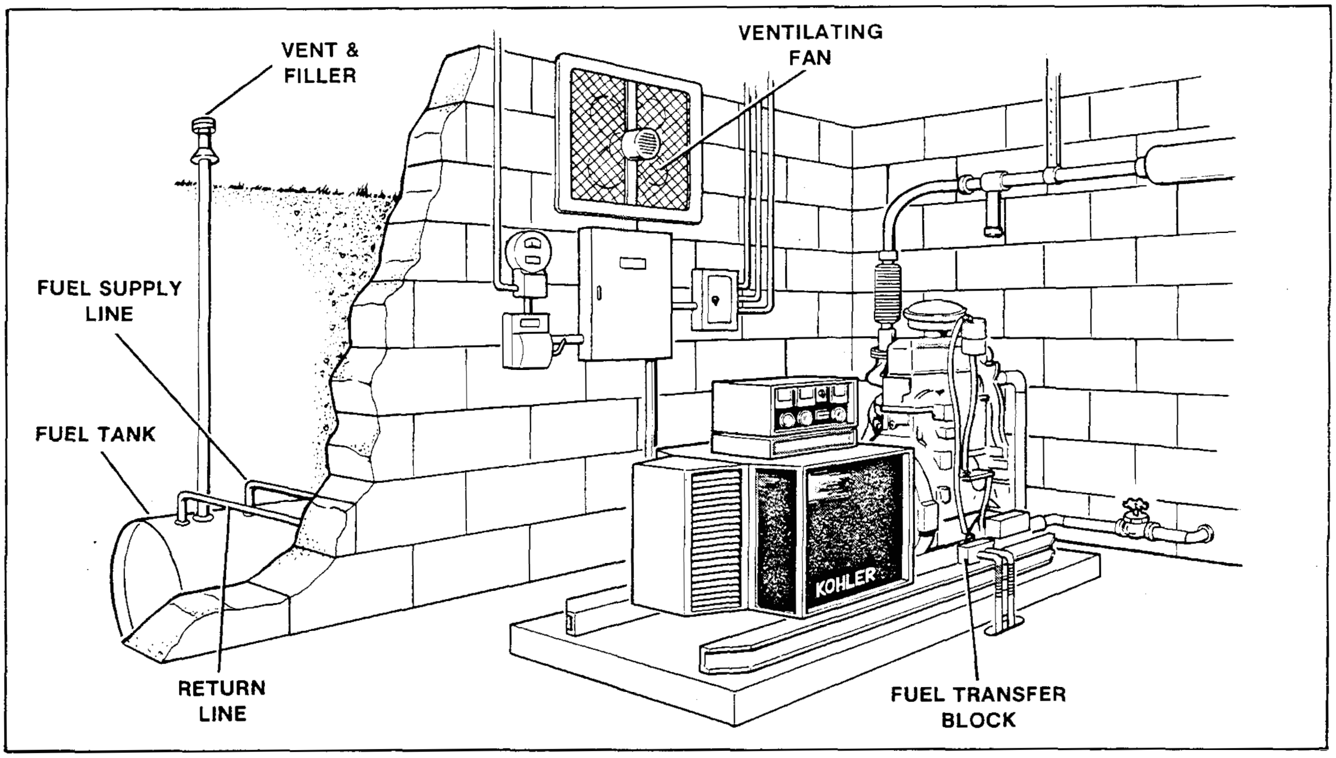


Figure 20. Gasoline System with Underground Fuel Tank

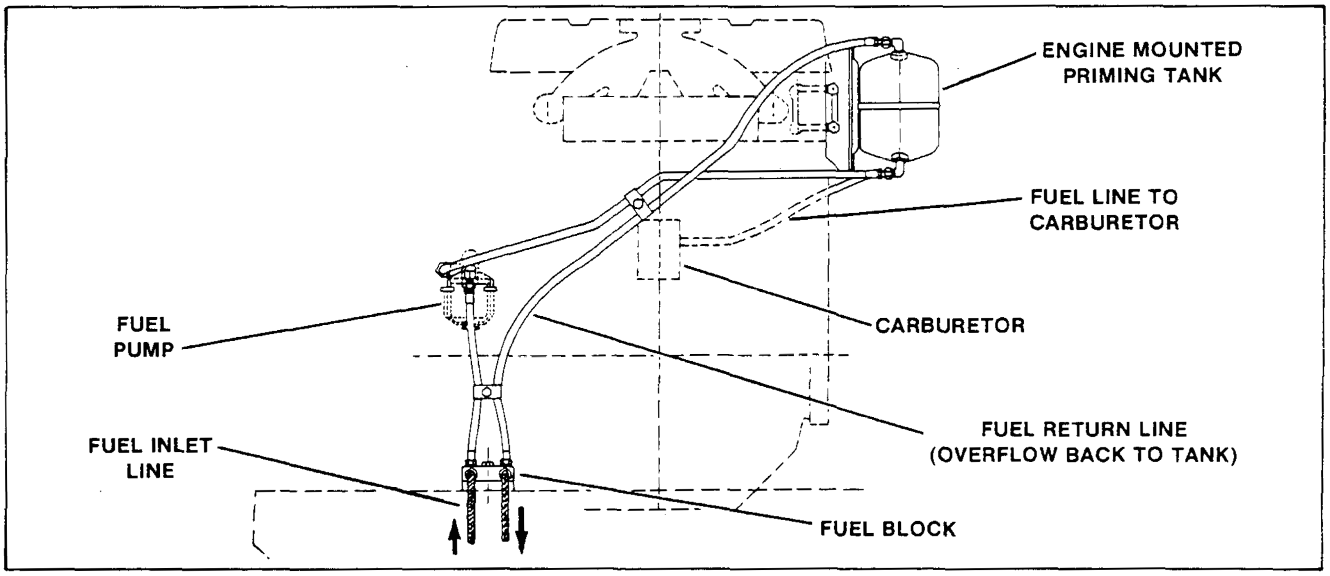


Figure 21. Liquid Fuel System with Priming Tank

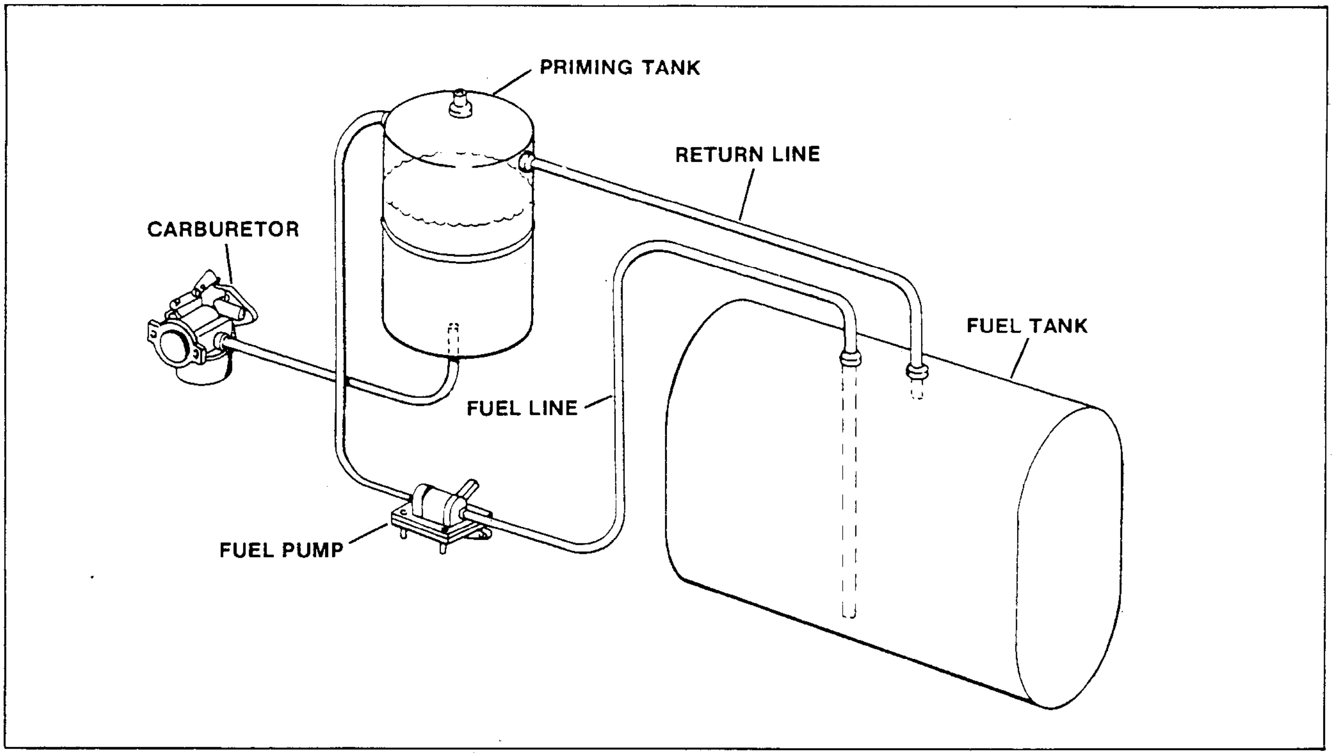


Figure 22. Schematic, Gasoline System with Priming Tank

GASOLINE FUEL TANKS:

In most cases, the main fuel tank must be located at a level not higher than the float bowl of the carburetor. If this is not done, the fuel may have sufficient head or gravitational pressure to unseat the needle valve and leak through the carburetor into the engine while the set is idle. If the main tank must be located above the level of the carburetor, the fuel system must include positive means of shutting off the gasoline while the set is not operating. Some type of anti-siphon device must be used to prevent siphoning action from the tank should a break in the fuel line occur. When the generator set is shut down, the fuel is held back by the fuel pump and the action of the carburetor float valve. Should there be a defect in the carburetor float valve or a break in the fuel line, the fuel from the tank will run through the line and empty into the room. The most effective means of preventing this is the inclusion of a small anti-siphon hole in the fuel line which will allow air to enter the line thus stopping the flow of fuel from the tank. This hole should be about the size of a No. 75 drill and is usually located in the top portion of the dip tube inside the tank.

The following factors must be considered when selecting the right size of main tank (Figure 23) for the particular installation:

1. Fuel consumption per hour.
2. The operational hours required between refilling.
3. Time required for supplier to replenish fuel.

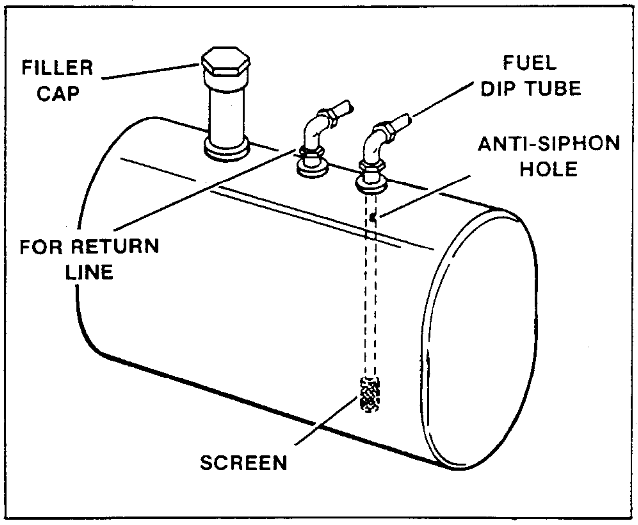


Figure 23. Fuel Tank Construction Details

The fuel consumption depends on the particular model plus the load at which the set will be operated. The fuel consumption figures at various load levels are given in each model's Specification Sheet.

The fuel storage tanks must be of adequate size to sustain operation during the longest anticipated period between refilling. Reserve capacity should be allowed to compensate for emergencies when fuel cannot be delivered on schedule. When considering the reserve factor, remember that gasoline has a tendency to deteriorate if stored longer than 6 months. If anticipated operation time requires a large storage tank, a portion of the fuel remaining in the tank may lead to fuel system problems. Additives which are available to prevent formation of gum should be used, especially on stand-by applications where fuel can be expected to remain in the tank for several months. Such additives are only a help - gasoline should never be stored for more than 6 months.

Diesel

Since diesel fuel is less volatile than gas or gasoline, it may be considered safer fuel from the standpoint of storage and handling. This is often reflected in less stringent regulations for placement of tanks. In some locations, main tanks of considerable size are permitted inside the building or enclosure; however, local regulations must be checked before planning the installation.

The very fact that diesel fuel is relatively safe can lead to careless installation practices resulting in poor performance of the engine and generator set. Diesel fuel may not leak out of an improperly tightened fitting; however, air can be drawn in through this loose fitting when the engine is operating. Air trapped in the fuel causes erratic performance and hard starting. For this reason, piping must be completely sealed against entrance of air and fine dust or dirt.

Fuel filters and sediment drains must be easily accessible for regular and frequent service. Cleanliness of the fuel is especially important on diesel engines which have easily clogged, precision fuel injectors and pumps. Black iron pipe or steel tubing must be used for diesel fuel systems - galvanized tanks and piping must not be used since the diesel fuel and the galvanized coating react chemically to produce flaking which quickly clogs filters or causes failure of the fuel pump or injectors. Flexible lines must be of the type approved for diesel fuels.

MAIN TANKS:

All main tanks should be vented so that air and other gases can escape to the atmosphere. The vent must prevent dust, dirt and moisture from entering the tank. Where return lines are required, keep the return spaced at least 12 inches (30.5 cm) away from the pick-up or fuel dip tube - if this is not done, air bubbles could be entrained in the fuel and cause erratic operation. At least 5% capacity should be allowed in a diesel main tank for expansion of the fuel. If the main tank is to be located overhead, a fuel shut-off solenoid should be used to prevent hydraulic lock or tank overflowing due to excessive pressures caused by static head of fuel. See Figure 24.

The best location for the main fuel tank is on the same general level as the fuel injection pump but lower than the injectors. Frequently, the tank must be placed higher or lower, requiring use of transfer or float tanks. When the main tank can be located close to the set and where the vertical lift is 5 feet (152 cm) or less, the fuel injection pump may be capable of supplying sufficient fuel. If the horizontal run is too great and/or the vertical height exceeds 5 feet (152 cm), an auxiliary pump is required. Generally when static head and dynamic suction (horizontal head) exceeds 6" (15.2 cm) hg (column mercury) the auxiliary pump and tank are required. A float tank or priming tank is usually required with the auxiliary pump. The auxiliary pump should be of the non-positive displacement type operated electrically off battery output voltage. This type pump prevents overfilling of tanks or injectors since it will cease pumping when back pressure gets too great.

PRIMING TANKS:

These are small capacity, 1 gallon (3.78 litre) maximum, tanks mounted approximately one foot (30.5 cm) above the level of the fuel pumps. They provide a small quantity of gravity fed fuel for starting purposes. If a generator set is idle for a considerable length of time, fuel in the pump and

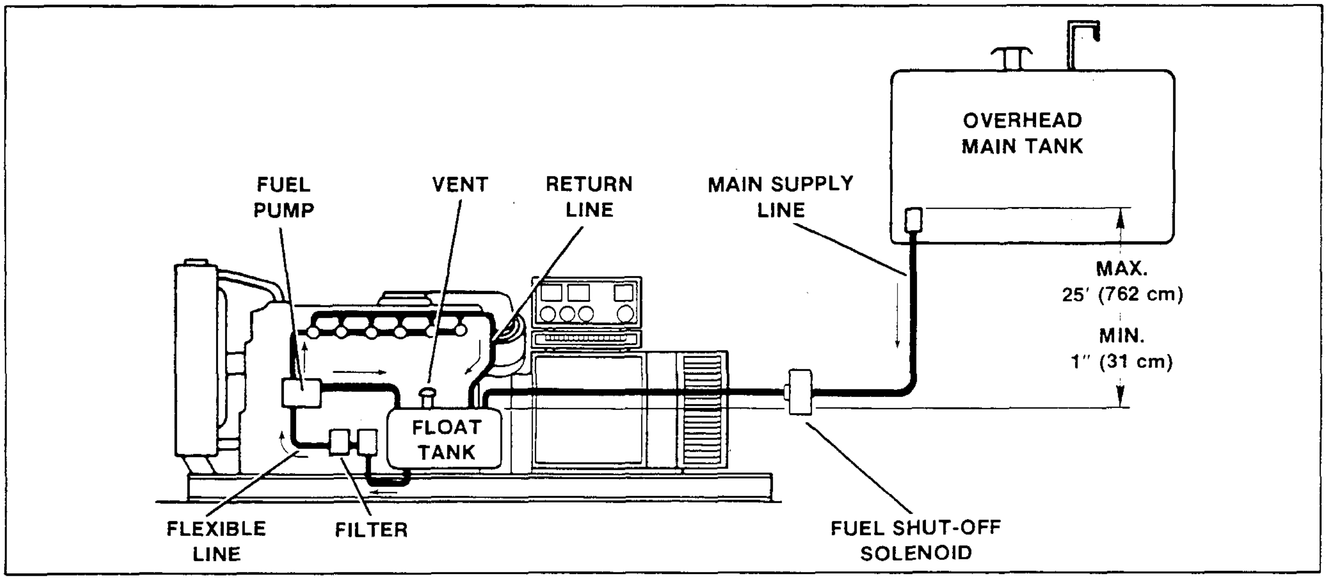


Figure 24. Schematic, Diesel System with Overhead Main Tank and Float Tank

lines is likely to drain back to the main tank. The priming tank holds sufficient fuel for starting and sustaining operation until the lines from the main tank are again full. This eliminates starting problems and delays caused by fuel drain back.

On certain diesel models, priming tanks cannot be used for even a slight head of fuel can cause leakage through the injectors and result in hydraulic lock problems.

FLOAT TANKS:

Return lines from the injectors and pump can be much shorter with a float tank - they run only to this tank, rather than extending back to the main tank. The float tank can be used with an electrically operated auxiliary fuel pump which lifts the fuel from a main tank located below the level of the fuel pump. See Figure 25. With this arrangement, the float device activates the auxiliary pump after the float drops to the low level and turns it off as the maximum or full level is again reached. A float tank can also be used with an overhead tank arrangement as shown in Figure 24.

NOTE

Float tanks should not be used with Positive Displacement Auxiliary Fuel Pumps.

If sufficient head is available for gravity feed, an auxiliary pump is not needed. An electric fuel shutoff valve must be used with the overhead tank system. Without this valve, fuel could leak out of the vent in the float tank.

TRANSFER TANKS:

Transfer tank systems function much the same as float tank systems except for greater capacity and lift abilities. See Figure 26. An electrically operated fuel level control switch is used to turn on the positive displacement auxiliary transfer pump. The switch activates the pump when the fuel in the transfer tank drops to a certain level, then turns the pump off when the fuel reaches a predetermined level.

The Kohler transfer tank kit prevents hydraulic lock on units where a slight head pressure may cause fuel leakage through the injectors. A return line back to the main fuel tank prevents flooding out of the transfer tank in the event the control switch malfunctions to allow the transfer pump to work continuously. Although the transfer tank should be located as close to the engine as possible, the pump can be remote mounted for installations in which the main supply tank is greater than 20 feet (610 cm) below the transfer tank. If the main storage tank is located above the transfer tank an electric fuel shutoff valve must be used; without this valve there's nothing to keep the transfer tank from overflowing. When the transfer pump is used the solenoid valve can be controlled by the engine starting circuit. On applications where the transfer pump is NOT used the solenoid valve can be controlled by the float switch.

⚠WARNING

FIRE OR EXPLOSION! Transfer tanks with electrical pumps are designed for use with **diesel fuel only**. Fire or explosion may result from using them with gasoline or other volatile fuels.

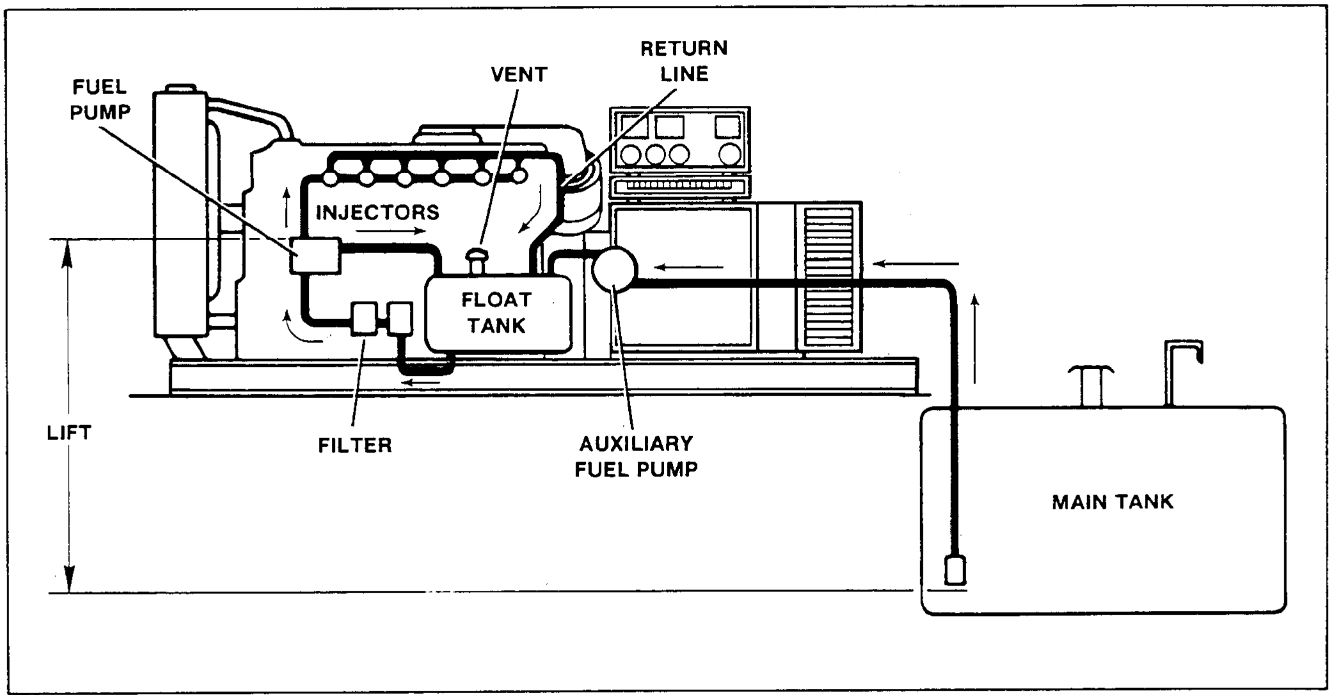


Figure 25. Schematic, Diesel System with Float Tank (Main Tank Below Fuel Pump)

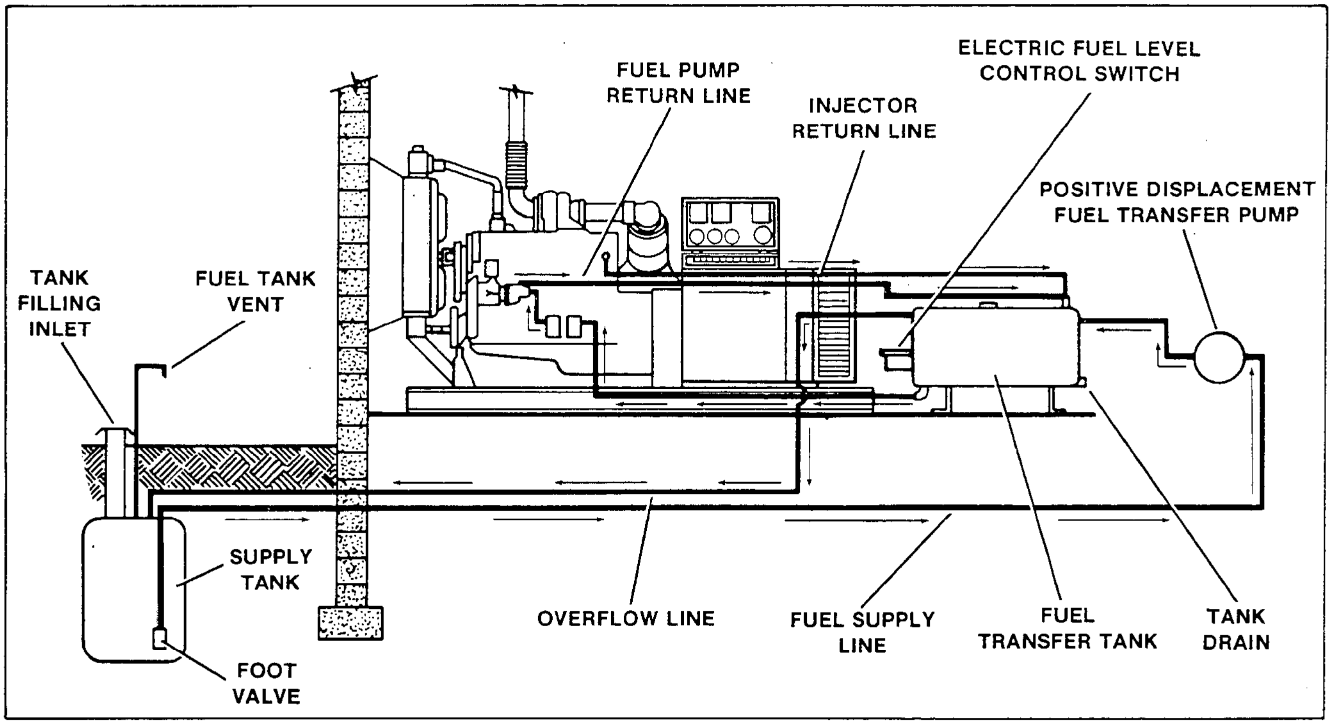


Figure 26. Fuel Transfer Tank

DIESEL FUEL RECOMMENDATIONS:

- #2D Diesel Fuel: A good quality 40 cetane (min.) #2-D Diesel fuel is best for most Kohler Diesel Generator Set Installations. This must be a distillate fuel which meets the requirements for #2-D in the ASTM Diesel fuel classification D-975-60T. Most major brands of fuel oils conform to the ASTM specification; however, #2-D Diesel must be stated to avoid mix-up with the #2 Domestic type furnace oil which may be unsatisfactory as an engine fuel.

- #1-D Diesel Fuel: A #1-D grade 40 cetane (min.) Diesel fuel may be best if operating at altitudes above 5000 feet (1524 m) or in cold weather, below 40°F (4°C) conditions. Kerosene is included in the #1-D class of fuel. This fuel has a lower flash point (more volatile) and is of lower viscosity (flows more freely) than #2-D. Since #1-D is a drier fuel, 1 quart (0.95 lt) of lubricating oil should be added to each 100 gallons (378.4 lt) of fuel as this provides lubrication for the fuel injection pump and nozzles which normally rely on the higher lubricating properties of #2-D. The #1-D fuel must also conform to the ASTM specifications.

- #2 Domestic Type (Furnace) Oil or #4-D fuels: NOT RECOMMENDED

- #4-D Grade Fuels: (NOT RECOMMENDED): The high sulfur content plus low cetane rating of this class of fuel makes it unsuitable for Kohler Diesel Generator Set use.

Gas

The gaseous or gas fuel systems used can be grouped in four general classifications. The systems are covered in the following sequence:

1. Liquified Petroleum Gas (LPG)
2. Natural Gas (including manufactured gas)
3. Dual Fuel Systems (natural and LP gas)
4. Combination Gas-Gasoline.

⚠WARNING

DANGEROUS FUELS! Use extreme caution when handling, storing and using fuels. All fuels are highly explosive in a vapor state. Store fuel in a well-ventilated area away from spark producing equipment and out of the reach of children. Never add fuel to the tank while the engine is running to prevent spilled fuel from igniting on contact with hot parts or from ignition spark. Keep fuel lines and connections tight and in good condition — don't replace flexible fuel lines with rigid lines. Flexible sections are used to avoid breakage due to vibration. Additional precautions should be taken when using the following fuels:

Propane (LP): Adequate ventilation is mandatory. Propane is heavier than air; install gas detectors low in room. Inspect detectors often.

Natural Gas: Adequate ventilation is mandatory. Natural gas rises; install gas detectors high in room. Inspect detectors often.

GAS PIPING:

Gas piping must never be used to ground electrical apparatus. Piping must be rigidly mounted but protected against vibration. Where flexible connections are required, use only UL approved connections. A flexible section should be used between the point where the gas leaves the solid fuel line and enters the engine. See Figure 27.

All gas lines and piping should be of the black iron type. Joints and connections must be securely fastened and sealed so that the gas will have no opportunity to escape. The pipe should be of sufficient size to maintain pressure level. The gas consumption of the various sets at different loads is listed in each model's Specification Sheet. In addition to the actual fuel consumption, the following factors must be considered:

1. Pressure loss due to number of fittings.
2. Specific gravity of gas.
3. Pressure loss due to length of piping.

Table 6 in the "Application Data" section at the back of this manual lists the capacity of various sizes and lengths of pipes.

MAIN COMPONENTS:

While regulators used in a gaseous fuel system are designed to close and stop fuel the instant the engine stops, they should not be relied upon to completely seal the fuel system. A ruptured diaphragm or a piece of grit could prevent the valves from seating with a result that gas would continue flowing through the carburetor into the engine and out into the surrounding air. The vent in the regulator should be plumbed with a small tube to the outside of a building or some other location where gas will not collect in an explosive mixture.

The common components of a gas system are as follows:

- Primary regulator - This regulator is used to provide initial control of the gas as it comes off the transmission lines, or with LPG, from the tank. The primary regulator reduces line pressures to allowable inlet pressures for the secondary regulators on the system.
- Secondary regulator - This low pressure type regulator admits fuel to the carburetor in response to engine demand similar to the float valve in a gasoline carburetor. Natural gas and LPG vapor withdrawal inlet pressures usually range from 4 to 6 ounces per square inch .018 to .026 kg/cm^2.

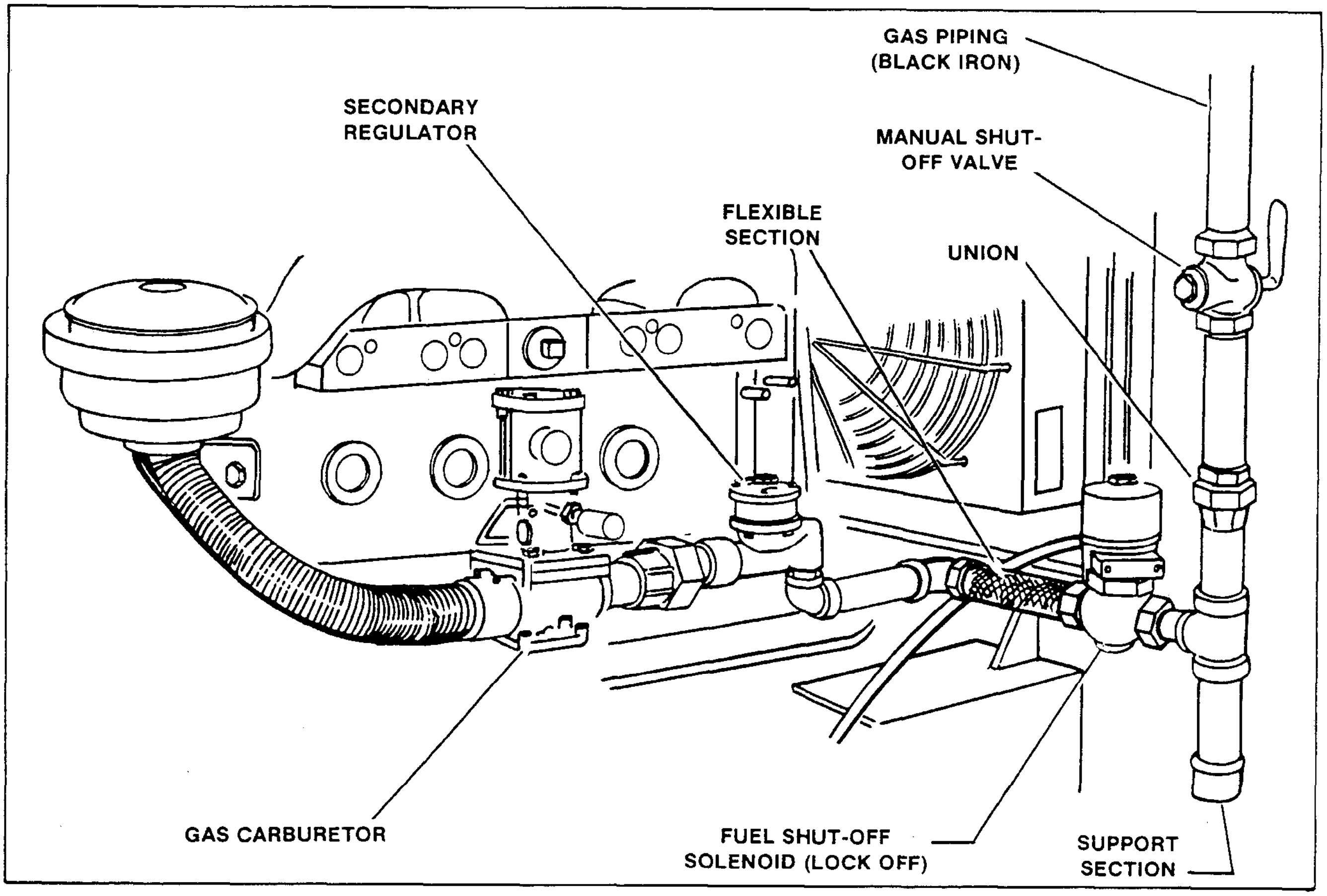


Figure 27. Components of a Typical Fuel System

- Fuel shut-off - This device automatically shuts off the fuel supply when the engine stops. Most lock-offs or automatic fuel shut-off valves use electrically activated solenoids that seal off the fuel the instant the ignition switch is turned off.
- Carburetor - Carburetor can be of two types - the gas-gasoline carburetor, which allows the engine to run on either gasoline, or the straight gas carburetor which operates on gaseous fuels.

LP Gas

FUEL CHARACTERISTICS:

LPG is supplied as a liquid in pressure tanks. It is easily adaptable to stationary applications where complete independence of an outside fuel supply is required. Furthermore since LPG does not deteriorate in long periods of storage as gasoline is known to do, a large supply of fuel can be kept on hand indefinitely for operation during emergency conditions.

⚠WARNING

DANGEROUS FUELS! Use extreme caution when handling, storing and using fuels. All fuels are highly explosive in a vapor state. Store fuel in a well-ventilated area away from spark producing equipment and out of the reach of children. Never add fuel to the tank while the engine is running to prevent spilled fuel from igniting on contact with hot parts or from ignition spark. Keep fuel lines and connections tight and in good condition — don't replace flexible fuel lines with rigid lines. Flexible sections are used to avoid breakage due to vibration. Additional precautions should be taken when using the following fuels:

Propane (LP): Adequate ventilation is mandatory. Propane is heavier than air; install gas detectors low in room. Inspect detectors often.

LPG is propane, butane, or a mixture of the two gases. The accompanying chart (Figure 28) shows the approximate vapor pressure of the two fuels at varying temperatures.

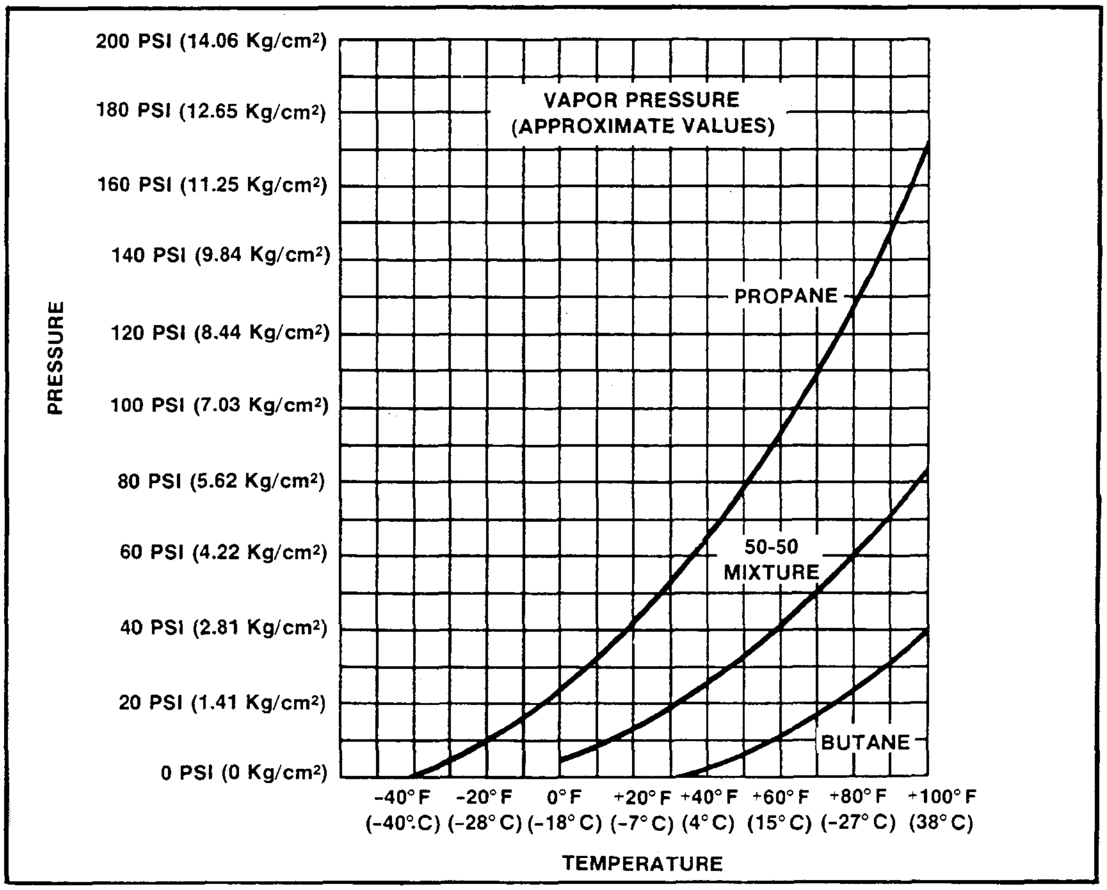


Figure 28. Vapor-Pressure Curve

The ratio of butane to propane is especially important when a large outdoor tank is used - a fuel supplier may fill the tank in warm summer months with a mixture composed mainly of butane; however, this mixture may not provide sufficient vaporized pressure at extremely cold temperatures to start and operate the engine. The user should specify the exact mixture which would permit operation under all temperature conditions.

Since LPG is supplied in pressurized tanks in liquid form, it must be converted to vapor state before being introduced into the carburetor. There are 31.26 cubic feet (0.88 m^3) of BUTANE gas in each gallon (3.78 lts) of liquid, and 36.39 cubic feet (1.03 m^3) of PROPANE in each gallon of liquid. See the individual Specification Sheets for fuel consumption at different loads, and contact your local fuel supplier for information regarding tank sizes.

VAPOR WITHDRAWAL SYSTEMS:

The liquid level in LPG tanks must not exceed 90% of the tank capacity. Generally 10 to 20 percent of capacity is allowed for expansion of the gas from liquid to vapor state. A vapor withdrawal system utilizes vapor forming in the space above the liquid. Temperature of the air surrounding the tank must be high enough to sustain adequate vaporization of the liquid fuel. In the colder climates, an independent heat source may be necessary to supplement natural vaporization within the tank. Refer to the LPG vapor pressure chart (Figure 28). Straight butane gas has little or no vaporization pressure in temperatures below +40° F (4° C). Even at +70° F (21° C) the pressure is only approximately 18 psi (1.26 Kg/cm^2). Some primary regulators will not operate if tank pressure drops below +30 psi (2.11 Kg/cm^2) while others operate at incoming pressures down to 3-1/2 to 5 psi (0.25 to 0.35 Kg/cm^2). Obviously, the fuel mixture and its vaporization pressure at the anticipated temperatures influences the selection of regulatory equipment. The components of the vapor withdrawal system used in a typical stationary application are shown in Figure 29.

Natural Gas

Natural gas is in a vapor state as supplied from the various utilities. This fuel system, therefore, consists of the same basic components and is used in the same general sequence as LP gas systems. When the heating content of the fuel falls below 1000 BTU, as it does with manufactured sewage and some natural gas fuels, the set will not produce rated power.

The primary regulator may or may not be furnished by the supplier. It is the responsibility of the supplier to insure that sufficient pressure is present at all times to operate the primary regulator. Installation, repair and alteration to gas piping should be undertaken only by the supplier or personnel authorized by him. Piping should never be used to ground any electrical apparatus. The piping should be rigidly mounted but protected against damage from vibration. Where flexible connections are needed, only U.L. approved flexible connections should be used. See Figure 30.

⚠WARNING

DANGEROUS FUELS! Use extreme caution when handling, storing and using fuels. All fuels are highly explosive in a vapor state. Store fuel in a well-ventilated area away from spark producing equipment and out of the reach of children. Never add fuel to the tank while the engine is running to prevent spilled fuel from igniting on contact with hot parts or from ignition spark. Keep fuel lines and connections tight and in good condition — don't replace flexible fuel lines with rigid lines. Flexible sections are used to avoid breakage due to vibration. Additional precautions should be taken when using the following fuels:

Natural Gas: Adequate ventilation is mandatory. Natural gas rises; install gas detectors high in room. Inspect detectors often.

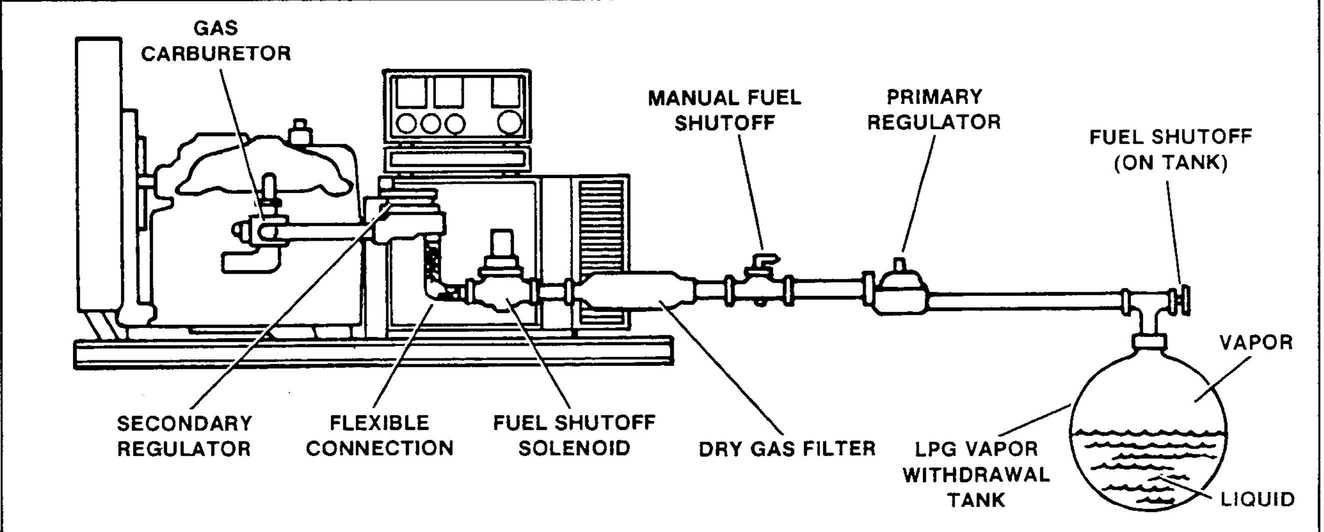


Figure 29. Schematic, LPG Vapor Withdrawal System

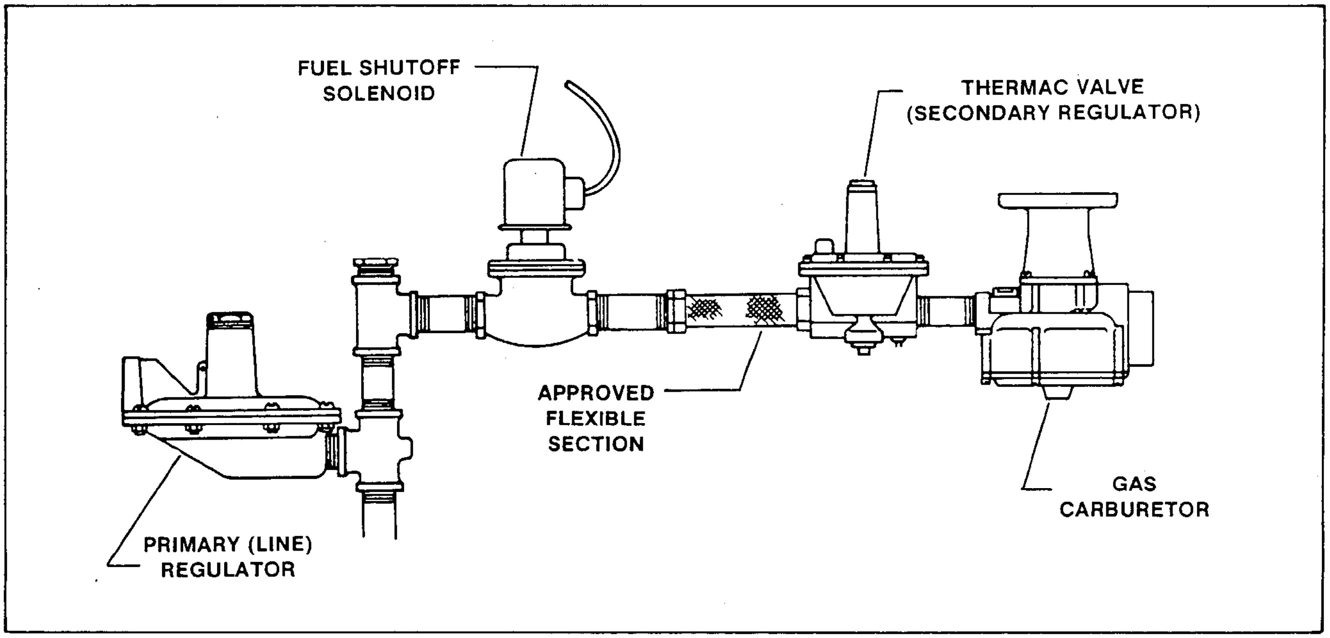


Figure 30. Components of a Typical Natural Gas Fuel System

Dual Systems (Natural & LPG)

In many applications, natural gas is the main fuel and LPG is used as the emergency fuel when natural gas is not available.

The dual fuel system in common use offers automatic changeover from one fuel to the other This is accomplished by the use of two separate regulators - the primary (line pressure) regulator for natural gas and a vacuum operated regulator for LPG. During operation on natural gas, pressure existing in the common line to the carburetor closes off the LPG regulator. Cutting off the natural gas creates a partial vacuum in the line which automatically opens the LPG regulator. The LPG regulator also serves as a vaporizer. To ensure proper carburation upon changeover to LP gas, a separate LP gas load adjustment is located in-line between the atmospheric regulator and the carburetor.

Combination Gas-Gasoline

Most engines, especially the smaller models, will operate successfully on gas or gasoline without extensive modification or complicated mechanical changeover. With a combination gas-gasoline fuel system, changeover involves only a few simple steps.

These systems normally utilize a gaseous fuel as the major fuel with gasoline for emergency operation. In some areas natural gas is available at reduced cost on an "interrupted service" basis - or in other cases a by-product gas may at times be unavailable. Continued operation is assured under these conditions by switching over to gasoline.

Either a combination gas-gasoline carburetor or a gasoline carburetor with gas adapter is used. Natural, manufactured sewage and LPG can be used with these carburetor combinations.

With the exception of the carburetor and addition of a gas adapter, the combination gas-gasoline systems utilize the same basic components as those in the natural and LPG systems. See Figure 31.

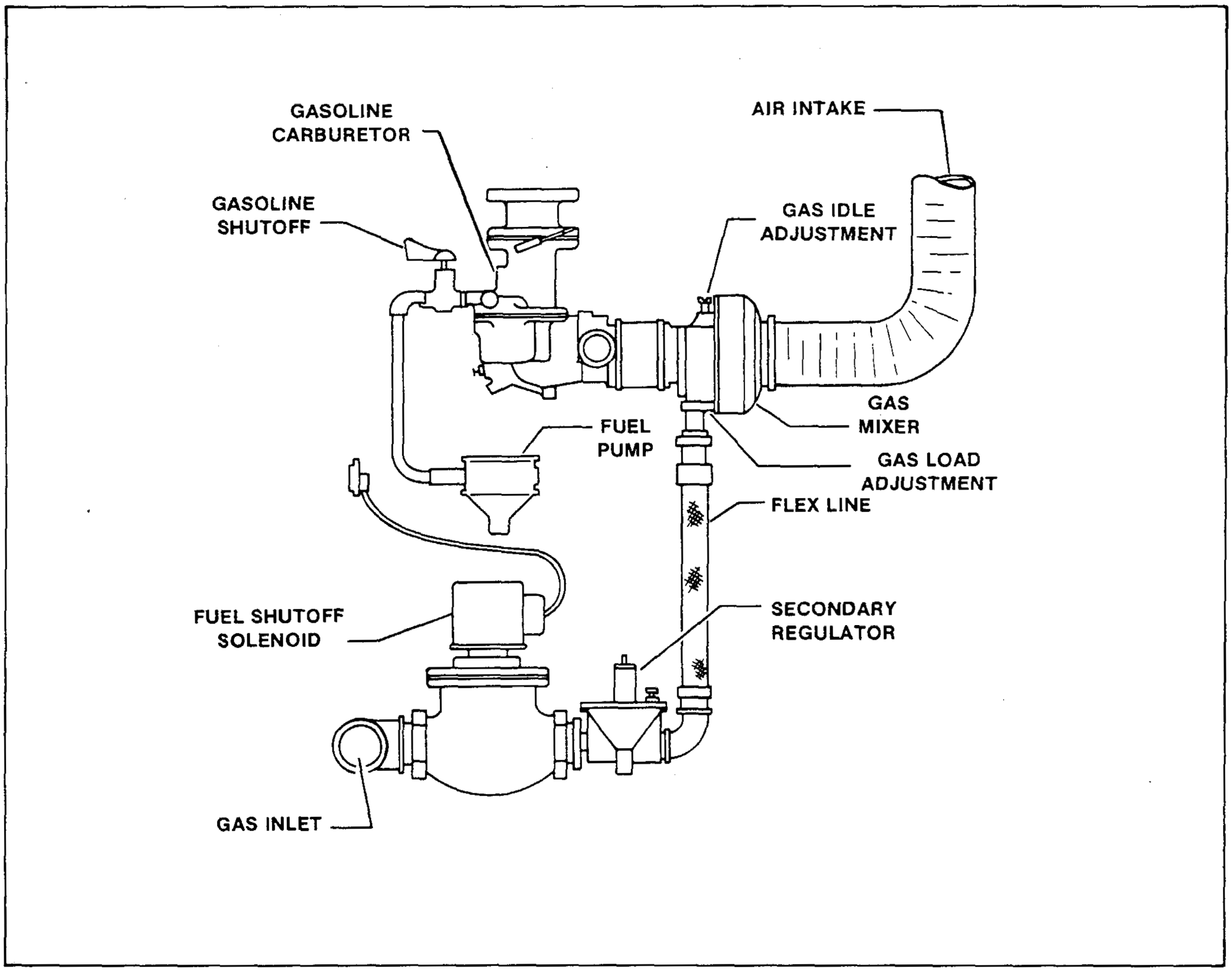


Figure 31. Combination Gas-Gasoline Fuel Systems

Electrical Requirements

To secure the fullest use of the current generated by Kohler Generator Sets, it is essential that the wiring be of the right size and properly installed. A reliable electrician should be engaged to install the wiring. Before the set is installed, provision should be made for installation of the transfer switch, the conduit, and other electrical connections required for the proper application of the set. All wiring must enter the set through flexible cables in order to reduce the transmission of vibration through the electrical lines. Applicable local and national codes should always be observed and carefully followed when installing a wiring system.

Batteries

Locate batteries in a clean dry area. Position them so that the caps are readily accessible for checking the level of the electrolyte. Keep batteries out of areas subject to excessively high temperatures. Locate them close to the set to keep cables short and thus insure maximum output. See Figure 32. Several types of battery racks are depicted in illustrations throughout this manual - refer to these for construction detail and suggested placement of battery racks. Run the positive battery cable to the starter motor on the set, (battery connection on the solenoid) and the negative battery cable to an appropriate ground. Battery requirements are listed in the individual Specification Sheets for each model.

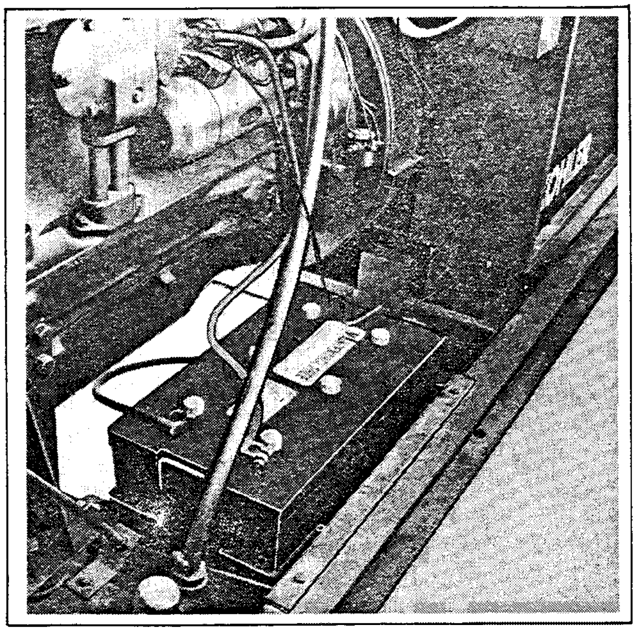


Figure 32. Battery Rack Placement

Battery Chargers

Kohler Generator offers float-type and trickle-type battery chargers for use with standby generator sets. The float-type charger complies with National Fire Protection Association (NFPA) 110 code for battery chargers.

Locate battery charger near the generator set (Figure 33), and connect the power cord to a normal 120 volt AC source. Many chargers have reconnection taps allowing operation at 208 or 240 volts, single phase, AC 50 or 60 cycle. Leads from a transfer switch-mounted battery charger should be run in separate conduit from those used for generator load cables, or remote engine-start circuits.

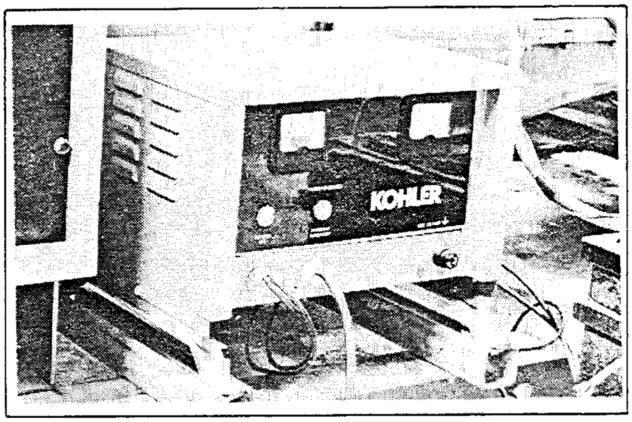


Figure 33. Battery Charger Location

Connect the red charger lead to the plus (+) terminal on the battery and the black charger lead to the negative (-) battery terminal. The charging leads may also be connected to the battery connections on the generator set. Kohler battery chargers designed for NFPA 110 applications are equipped with charger malfunction and low battery voltage circuits. These circuits may be connected to controller or customer provided fault indicators to alert the operator of fault conditions. For charger details refer to the Kohler Battery Charger Specification Sheet available from your Kohler Generator Distributor, or the Kohler Generator Division, Marketing Department. For complete operating instructions refer to the Kohler Battery Charger operating manual accompanying the charger.

⚠WARNING

EXPLOSIVE BATTERY GASES! The gases generated by a battery being charged are highly explosive. Do not smoke or permit flame or spark to occur near a battery at any time, particularly when it is being charged. Avoid contacting terminals with tools, etc., to prevent burns and to prevent sparks that could cause an explosion. Remove wristwatch, rings, and any other jewelry before handling battery. Any compartment containing batteries should be well ventilated to prevent accumulation of explosive gases. To avoid sparks, do not disturb battery charger connections while battery is being charged and always turn charger off before disconnecting.

Remote Engine-Start Circuit

Connections to the transfer switch engine-start terminals, or a remote manual engine-start switch, should use 14-gauge (AWG) wire and run in a conduit separate from those conduits used for generator load cables or battery charger leads. The remote engine-start circuit must be free of any other voltages.

Load Analysis

The lighting and appliance load is usually easiest to calculate – simply total wattage of lamps and appliances to be operated off the generator set. Make sure the total includes only lights and appliances actually on the set circuit. If motor starting is involved, don't overlook the high current demanded by the motor during start-up. The "in-rush" current may be 2-10 times higher during start-up.

Refer to Kohler G16-001, "Motor Starting Guide", for specific details. Reserve capacity must be allowed for "in-rush" demands plus any other loads which may be on line as the motor starts.

Line overvoltage protection may be needed to protect critical loads and sensitive applications. Overvoltage conditions may occur in commercial power as well as standby power systems. Equipment to protect against overvoltage is available from various manufacturers which specialize in that type of equipment. The type of protection needed will depend on the nature of your particular critical loads.

Load Lead Connections

When looking at a Fast-Response set from the generator end, remove the panel on the right side of the generator compartment to expose the main load leads. If the unit has an installed line circuit breaker, remove the panel on the left side to expose the leads. On the 300KW-1000KW sets remove the panel directly in front of you when looking at the generator end.

Route load leads away from the generator set through a flexible conduit. Leads may exit anywhere through the generator housing depending upon the accessibility of the emergency power leads to the transfer box. When making knock-outs on the generator housing, position them as to not block convenient removal of the controller lower tray. See Figure 34.

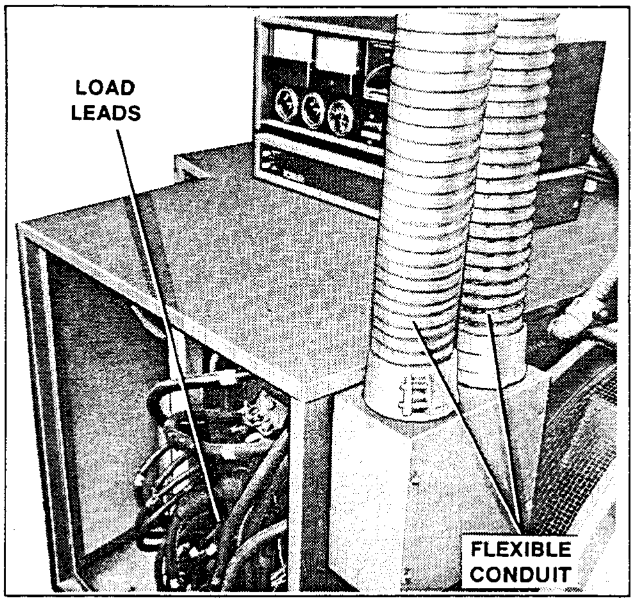


Figure 34. Load Lead Connections

Automatic Transfer Switches

A complete line of Kohler Automatic Transfer Switches is available for use with Standby Sets. These function to automatically transfer the electrical load to the Standby Set when the normal source fails, then switch the load back to the normal source when it is once again available. To do this, the panel must sense that the normal power has been cut or has fallen below acceptable voltage levels, then signal the Standby Set to start and transfer the load to standby as soon as the generator output reaches rated voltage. The transfer normally occurs within 5-10 seconds; however, time delays are often incorporated as options to delay transfer under momentary outage conditions or momentary fluctuations in voltage.

When normal power is again available, the switch transfers the load from standby back to the normal power source then initiates shut-down of the generator set.

⚠WARNING

DANGER OF ELECTROCUTION! When the generator is used for standby power, use of an automatic transfer switch is required to prevent inadvertent interconnection of standby and other sources of power. In some states and/or localities it is illegal to operate a standby generator without an automatic transfer switch. Failure to install an automatic transfer switch will cause "backfeed" into utility transmission lines and can cause serious injury or death.

Transfer switches serving emergency equipment and systems should provide for generator set and system exercise under 1/3-load or more for at least 30 minutes, at intervals of not-more-than seven days.

Generator Set Grounding

A grounding lug is provided for grounding the frame of the generator set. The National Electrical Code, Article 250, requires that the frame of the generator set be grounded to earth. The only exceptions are vehicle-mounted sets, where the frame of the vehicle serves as the ground, and portable generator sets supplying only portable equipment, where the frame of the generator set serves as the ground.

The National Electrical Code also requires that the non-current carrying parts of connected equipment and equipment ground conductor (green wire) be bonded to the generator set.

Remote Controls and Alarms

Most standby models can be equipped with remote annunciators (decision monitors), audio-visual alarms and emergency stop switches. These accessories will enable the generator set to meet the standards of National Fire Protection Association (NFPA) 99 and 110 for emergency power systems and also the standards of the National Electrical Code, Section 701-8. These codes require a battery-powered alarm indicator (remote annunciator or AV alarm) to operate outside the generating room in a location readily visible by operating personnel at a normal work station. The alarm indicator must give audio and visual warning of an alarm condition affecting an emergency or auxiliary power source. A manually-operated emergency stop switch must also be installed outside the room housing the generator set. The addition of an isolated alarm contact kit permits installation of additional customer provided alarms and accessories.

Remote Annunciator (Decision Monitor)

The remote annunciator allows monitoring of the standby power system from a location remote from the generator set. The annunciator panel can be either desk or wall mounted and up to three remote annunciators can be connected to the controller if desired. Specific information on annunciator indicator lamps and alarms is available by contacting Kohler Generator Division — Product Applications. To install the remote annunciator, refer to the instructions supplied with the Decision Monitor kit. Mount the connection box at a convenient location on the generator set skid or adjacent to the set. Use 18 or 20 gauge stranded wire to make all annunciator electrical connections.

Audio-Visual (AV) Alarm

An AV alarm warns the operator of fault shutdowns and pre-alarm conditions (except battery charger fault and low battery voltage) from a location remote from the generator. AV alarms include alarm horn, alarm silence switch and a common fault lamp. To install the AV alarm, refer to the instructions supplied with the kit. Use 18 or 20 gauge wire to make connections between AV alarm and controller terminal strip.

Emergency Stop Switch

The emergency stop switch allows immediate shutdown of the generator set from a station remote from the generator. If the emergency stop switch is activated, the emergency stop lamp lights and the unit shuts down. The generator cannot be restarted until the emergency stop switch is reset (by replacing glass face) and the controller is reset. The emergency stop switch should be installed outside the room housing the generator according to the instructions supplied with the kit. Use 18 or 20 gauge wire to connect emergency stop switch to controller terminal strip.

Isolated Alarm Contact Kit

The isolated alarm contact kit allows monitoring of the standby system and/or the ability to activate accessories from a location remote from the generator set. Customer provided warning devices (lamps, audible alarms) and/or accessories are typically connected to the set's overspeed, overcrank, high engine temperature, low oil pressure and low water temperature functions (if equipped). Mount the isolated alarm contact kit in any location, including on the generator set. The contact kit can be used as an alternate or in conjunction with the remote annunciator panel. To install the isolated alarm contact kit, refer to the instructions supplied with the kit.

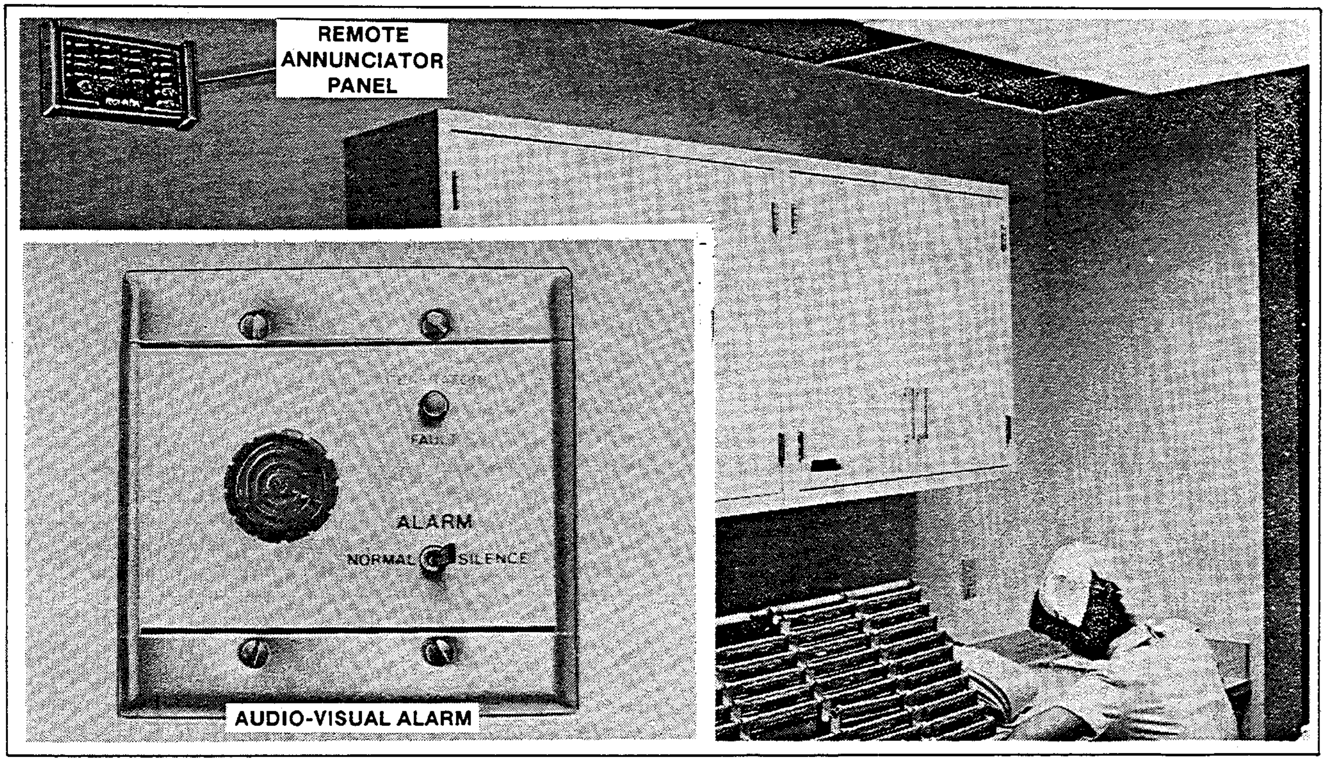


Figure 35. Kohler Alarm Indicators

Application Data

General

Information in this section is subject to change and should be used only as a guide to preliminary planning of an installation. For final plans, use details as supplied on certified prints and/or data furnished by Kohler Co. See Individual Model Specification Sheets for the following information:

- Weights
- Overall Dimensions
- Block Heater Specifications
- Crankcase Heater Specifications
- Radiator Capacity
- Crankcase Capacity
- Fuel Consumption
- Exhaust Outlet Size
- Fuel Inlet Size
- Battery Recommendations

Air Requirements

Air requirements for air cooled models are shown on the specification sheets divided into "Cooling Air" (engine and generator), and "Combustion Air". The total air required for a given generator set is the sum of these two quantities.

If an engine is equipped with an optional city water or remote radiator cooling system, air must be provided for generator cooling and to remove heat radiated from the engine. The recommended cooling air is the same for either system, and is shown on most specification sheets under "Operation Requirements." If no figure is shown for the air required, use at least 33% of the cooling air requirement for the standard unit mounted radiator system.

Exhaust Line Recommendations

Use Table 1 to figure nominal pipe size (NPT) for the outlet exhaust line. Find the exhaust outlet size (engine) in the left hand column. Then find the required pipe size under the exhaust line length. One elbow is equal in restriction to approximately 10 feet (3.05 m) of pipe. When figuring pipe size, add 10 feet (3.05 m) to exhaust line length (theoretically) for each elbow. Example: With outlet size of 1-1/2 inch and an exhaust line of 15 feet (4.57 m), the pipe size (NPT) should be 2 inches. With outlet size of 1-1/2 inch, an exhaust line of 15 feet (4.57 m), and one elbow, the pipe size (NPT) should be 3 inches.

NOTE

When elbows are required; recommend using sweep elbows with a radius of five times the diameter of the exhaust pipe being used.

Exhaust Thimble Diameters

The minimum outside diameter of a double thimble (inner and outer sleeves) should be at least six inches (15.24 cm) greater than the diameter of the exhaust pipe. With single sleeve thimbles, the O.D. should be at least 12 inches (30.48 cm) greater than the diameter of the exhaust pipe. The minimum thimble diameters for some common exhaust pipe sizes are listed in Table 2.

Exhaust Outlet Size (Engine)	Up to 10 Feet (3.05 m)	10 to 20 Feet (3.05 to 6.10 m)	20 to 70 Feet (6.10 to 9.14 m)	70 to 200 Feet (9.14 to 24.38 m)
1	1	1-1/4	1-1/2	2
1-1/4	1-1/4	1-1/2	2	3
1-1/2	1-1/2	2	3	3
2	2	3	3	4
3	3	3	4	5
3-1/2	3-1/2	4	4	5
4	4	4	6	8
5	5	5	8	8
6	6	6	8	10

Pipe sizes are in inches.

Table 1

EXHAUST THIMBLE — MINIMUM O.D.

Exhaust Pipe Diameter	Minimum Outside Diameter		Exhaust Pipe Diameter	Minimum Outside Diameter	
	Single Sleeve Thimble*	Double Sleeve Thimble**		Single Sleeve Thimble*	Double Sleeve Thimble**
0.5" (1.27 cm)	12.5" (31.75 cm)	6.5" (16.51 cm)	2.5" (6.35 cm)	14.5" (36.83 cm)	8.5" (21.59 cm)
0.75" (1.90 cm)	12.75" (32.38 cm)	6.75" (17.14 cm)	3.0" (7.62 cm)	15.0" (38.10 cm)	9.0" (22.86 cm)
1.0" (2.54 cm)	13.0" (33.02 cm)	7.0" (17.78 cm)	3.5" (8.89 cm)	15.5" (39.35 cm)	9.5" (24.13 cm)
1.25" (3.18 cm)	13.25" (33.65 cm)	7.25" (18.41 cm)	4.0" (10.16 cm)	16.0" (40.64 cm)	10.0" (25.40 cm)
1.5" (3.81 cm)	13.5" (34.29 cm)	7.50" (19.05 cm)	5.0" (12.70 cm)	17.0" (43.18 cm)	11.0" (27.94 cm)
2.0" (5.08 cm)	14.0" (35.56 cm)	8.0" (20.32 cm)			

*Diameter of Pipe Plus 12" (30.48 cm) **Diameter of Pipe Plus 6" (15.24 cm)

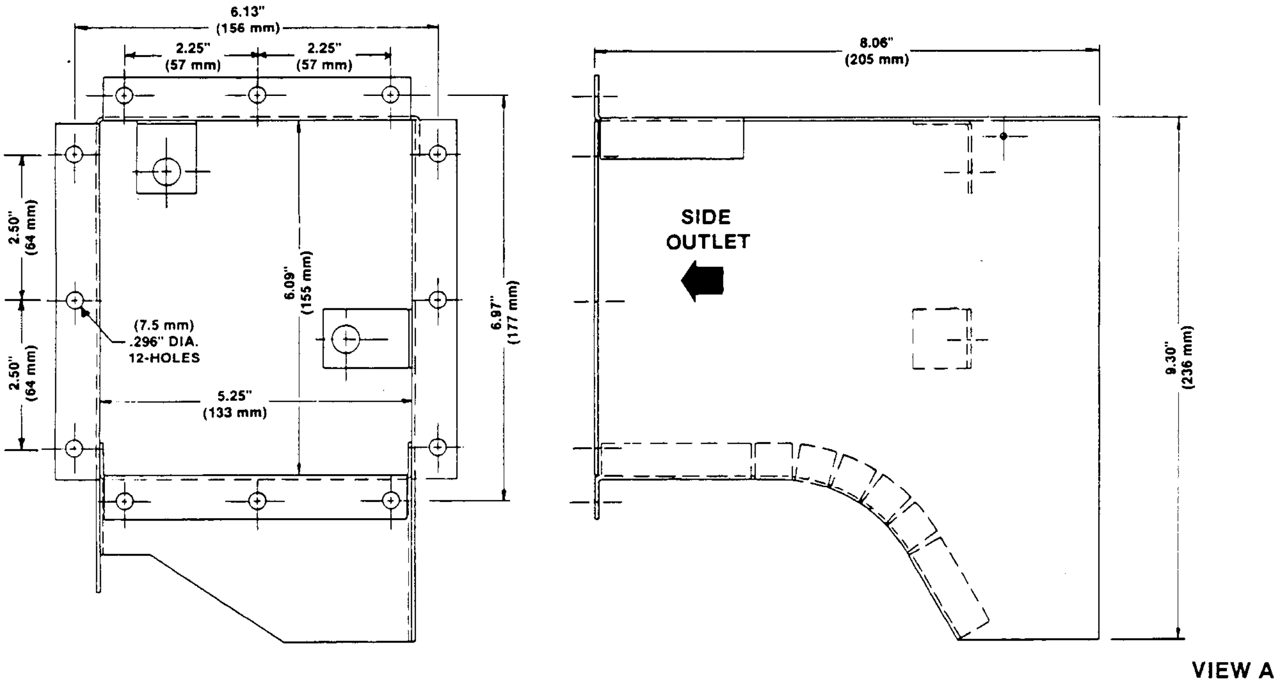
Table 2

Air Vac, Air Vent Duct Dimensions

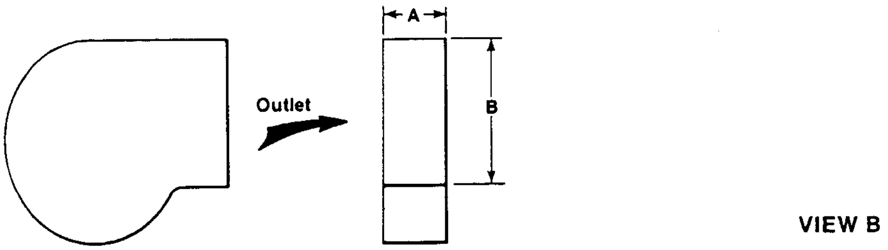
Model (kW)	Engine Model	Cooling Type	View	Duct Dimension A	Duct Dimension B
5.0	D-302-1	Air Vent	A	—	—
7.0	K-582	Air Vac	B	4-5/16" (109.5 mm)	9-1/4" (231.8 mm)
10.0	D-302-2	Air Vent	C	—	—
15.0	D-327-2	Air Vent	E	—	—
15.0	VG-4D	Air Vac	B	6-5/32" (155.9 mm)	12" (304.8 mm)
15.0	VG-4D	Air Vent	D	—	—

Table 3

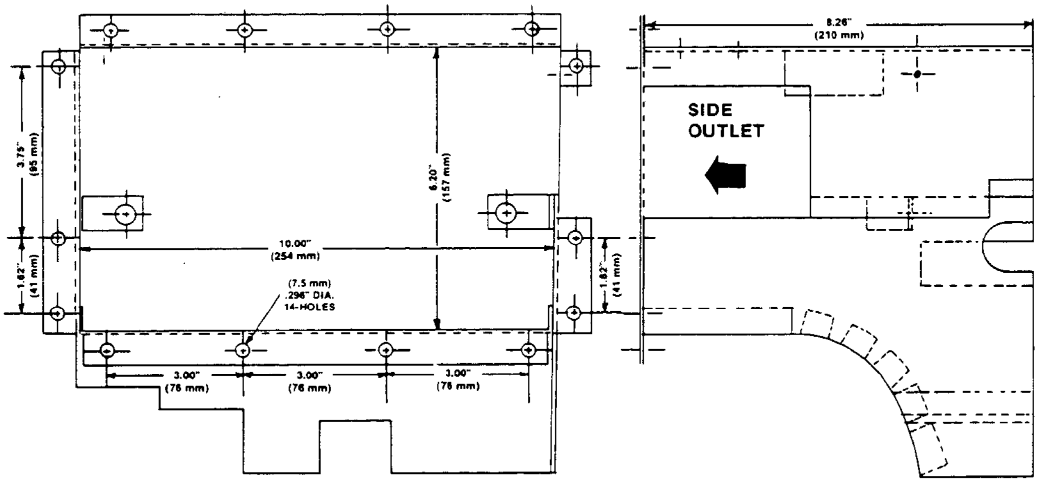
AIR VENT DIMENSIONS - DIESEL (D-302-1 MWM)



AIR VAC DIMENSIONS

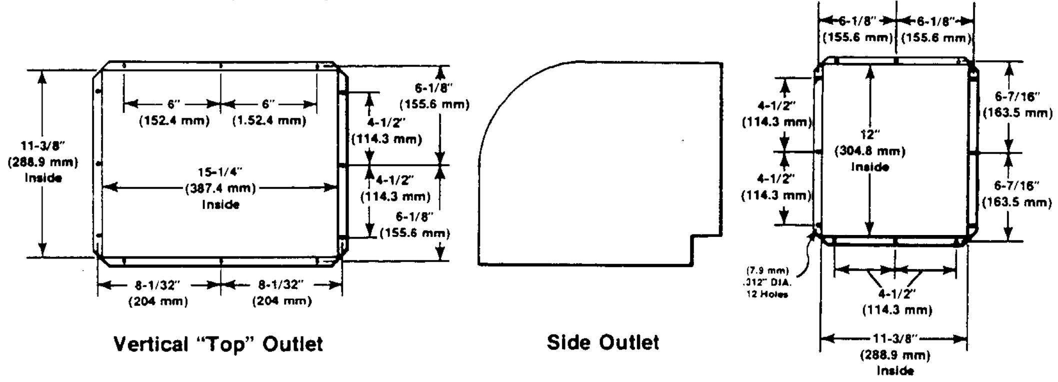


AIR VENT DIMENSIONS - DIESEL (D-302-2 MWM)



VIEW C

AIR VENT DIMENSIONS – (VG-4D)

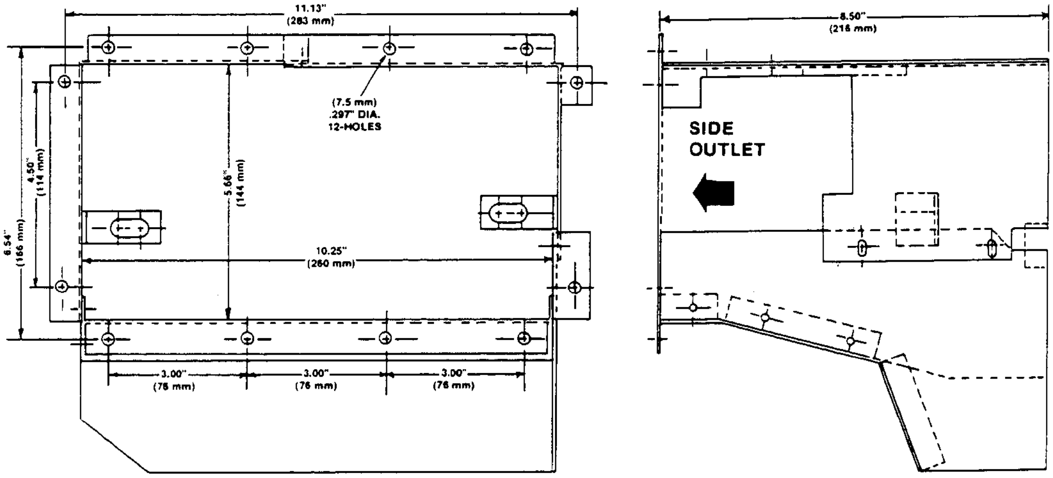


Vertical "Top" Outlet

Side Outlet

VIEW D

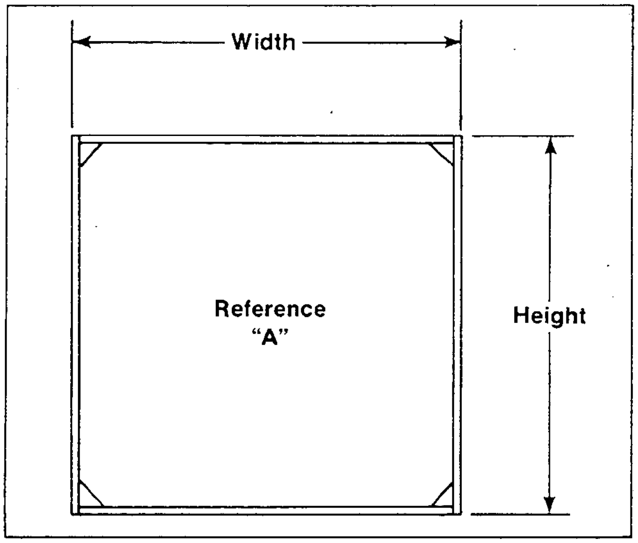
AIR VENT DIMENSIONS - DIESEL (D-327-2 MWM)



VIEW E

NOTE

On generator sets smaller than 4 kW, inlet must be at least 1 square foot (0.09 m^2). For larger sets allow 1/4 square foot (0.02 m^2) for each 1000 watts capacity. Outlet ductwork may be the same size as duct outlet if straight and less than 10 feet (305 cm) in length. See Table 3.



Radiator Air Duct Dimensions

NOTE

A vent at least 1-1/2 times larger than the air duct frame (Table 4) is recommended for the air outlet. Use ductwork from radiator frame to the opening vent. Air inlet opening must be at least as large (preferably larger) as the outlet. Increase size of opening for any restrictions.

Model (kW)	Engine Model	Air Duct Frame Kit	*Width Inches (mm)	*Height Inches (mm)
20	LSG-423	255169	23" (584.2 mm)	26" (660.4 mm)
20	4B	255169	23" (584.2 mm)	26" (660.4 mm)
30	CSG-649	255169	23" (584.2 mm)	26" (660.4 mm)
30	4B	255169	23" (584.2 mm)	26" (660.4 mm)
40	4B	255169	23" (584.2 mm)	26" (660.4 mm)
45	CSG-649	255169	23" (584.2 mm)	26" (660.4 mm)
50	LSG-875	253563	26-1/2" (673 mm)	30-1/4" (768 mm)
50	4BT	255169	23" (584.2 mm)	26" (660.4 mm)
60	LSG-875	253563	26-1/2" (673 mm)	30-1/4" (768 mm)
60	4BT	255169	23" (584.2 mm)	26" (660.4 mm)
70	LSG-875	253563	26-1/2" (673 mm)	30-1/4" (768 mm)
80	LSG-875	253563	26-1/2" (673 mm)	30-1/4" (768 mm)
80	6BT	253563	26-1/2" (673 mm)	30-1/4" (768 mm)
100	LSG-875	255472	31-1/2" (800 mm)	43-3/4" (1111 mm)
100	6BT	253563	26-1/2" (673 mm)	30-1/4" (768 mm)
125	6CT	254230	32-1/2" (825.5 mm)	34-1/4" (869.9 mm)
150	NTA-495	255472	31-1/2" (800 mm)	43-3/4" (1111 mm)
150	6CTA	254230	32-1/2" (825.5 mm)	34-1/4" (869.9 mm)
160	NT-855	290082	40-1/8" (1019.2 mm)	41-1/8" (1044.6 mm)
180	NT-855	290082	40-1/8" (1019.2 mm)	41-1/8" (1044.6 mm)
230	NT-855	290082	40-1/8" (1019.2 mm)	41-1/8" (1044.6 mm)
250	NT-855	290082	40-1/8" (1019.2 mm)	41-1/8" (1044.6 mm)
275	NTA-855	290082	40-1/8" (1019.2 mm)	41-1/8" (1044.6 mm)
300	NTTA-855	290082	40-1/8" (1019.2 mm)	41-1/8" (1044.6 mm)
350	NTTA-855	290082	40-1/8" (1019.2 mm)	41-1/8" (1044.6 mm)
400	KTA-1150	291534	42-1/2" (1082.7 mm)	41-3/4" (1063.6 mm)
450	KTTA-19	291534	42-1/2" (1082.7 mm)	41-3/4" (1063.6 mm)
500	VTA-1710	282731	52-1/4" (1327.1 mm)	50" (1270 mm)
600	VTA-1710	282738	56-1/2" (1435.1 mm)	55" (1397 mm)
750	KTA-2300	291641	64" (1625.6 mm)	62" (1574.8 mm)
1000	KTA-3067	291676	82-1/4" (2089.1 mm)	80-7/8" (2054.3 mm)

*See Reference "A"

Table 4

Remote Radiator Specifications

See the generator specification sheet for water flow and heat rejection data. Contact the radiator supplier for specific details on remote radiators.

Water Requirement — City Water Cooled

Water requirements for city water cooled systems are based on engine heat rejection and operating temperature. To determine water requirements for a particular city water cooled set, consult the generator set specification sheet.

Pipe Size — Gas Flow Chart

The type of fuel, the distance it must travel from gas meter/tank to fuel shutoff solenoid, and the amount consumed by the engine must all be considered when determining fuel line pipe size. To find the correction necessary for the different specific gravity of the particular fuel used refer to Table 6. The Pipe Size — Gas Flow Chart is based on a pressure drop which allows for a normal amount of restriction from fittings, etc. To figure the correct pipe size for a specific installation, refer to the chart and follow the procedure outlined below.

1. Determine length of pipe between gas meter/tank and fuel shutoff solenoid at generator set. *EXAMPLE:* 114 ft. (34.7 m).
2. Find figure closest to pipe length in "Length of Pipe" column on chart. *EXAMPLE:* 120 ft. (36.6 m).
3. Refer to fuel consumption on model specification sheet. Note type of fuel used, and cubic feet per hour (m^3/hr.) consumption at 100% load. *EXAMPLE:* 70 kW, Natural Gas — 1200 ft^3/hr. (34 m^3/hr.)
4. Refer to Correction Factors below. Locate factor for specific gravity of fuel used. *EXAMPLE:* Natural Gas specific gravity — .65, correction factor — .962.

CORRECTION FACTORS

Fuel	Specific Gravity	Factor
Sewage gas	0.55	1.040
Natural gas	0.65	0.962
Air	1.00	0.775
Propane	1.50	0.633
Butane	2.10	0.535

Table 6

5. Divide consumption figure (from No. 3) by correction factor. *EXAMPLE:* 1200 $ft.^3$/hr. (34 m^3/hr.) ÷ .962 = 1247 $ft.^3$/hr. (33 m^3/hr.).
6. Move horizontally across page from determined point in "Length of Pipe" column (120 ft. (36.6 m) in example). Stop at first figure equal to or greater than corrected consumption figure. *EXAMPLE:* 1340 $ft.^3$/hr. (38 m^3/hr.).
7. Move straight down from that figure to determine correct pipe size. *EXAMPLE:* At 1340 $ft.^3$/hr. (38 m^3/hr.), Pipe Size — 2-1/2" IPS.

Length of Pipe Feet (Meters)	Fuel Consumption in Cubic Feet Per Hour (Cubic Meters Per Hour)										
15 (4.6)	76 (2.2)	172 (4.9)	345 (9.8)	750 (21.3)	1220 (34.6)	2480 (70.4)	3850 (109.3)	6500 (184.6)	13880 (394.2)	38700 (1099.1)	79000 (2243.6)
30 (9.1)	52 (1.5)	120 (3.4)	241 (6.8)	535 (15.2)	850 (24.1)	1780 (50.6)	2750 (78.1)	4700 (133.5)	9700 (275.5)	27370 (777.3)	55850 (1586.1)
45 (13.7)	43 (1.2)	99 (2.8)	199 (5.6)	435 (12.4)	700 (19.9)	1475 (41.9)	2300 (65.3)	3900 (110.8)	7900 (224.4)	23350 (663.1)	45600 (1295.0)
60 (18.3)	38 (1.1)	86 (2.4)	173 (4.9)	380 (10.8)	610 (17.3)	1290 (36.6)	2000 (56.8)	3450 (98.0)	6800 (193.1)	19330 (549.0)	39500 (1121.8)
75 (22.9)		77 (2.2)	155 (4.4)	345 (9.8)	545 (15.5)	1120 (31.8)	1750 (49.7)	3000 (85.2)	6000 (170.4)	17310 (491.6)	35300 (1002.5)
90 (27.4)		70 (2.0)	141 (4.0)	310 (8.8)	490 (13.9)	1000 (28.4)	1560 (44.3)	2700 (76.7)	5500 (156.2)	15800 (445.9)	32250 (916.0)
105 (32.0)		65 (1.8)	131 (3.7)	285 (8.1)	450 (12.8)	920 (26.1)	1430 (40.6)	2450 (69.6)	5100 (144.8)	14620 (415.2)	29850 (847.7)
120 (36.6)			120 (3.4)	270 (7.7)	420 (11.9)	860 (24.4)	1340 (38.0)	2300 (65.3)	4800 (136.3)	13680 (388.5)	27920 (792.9)
150 (45.7)			109 (3.1)	242 (6.9)	380 (10.8)	780 (22.2)	1220 (34.6)	2090 (59.4)	4350 (123.5)	12240 (347.6)	25000 (710.0)
180 (54.9)			100 (2.8)	225 (6.4)	350 (9.9)	720 (20.4)	1120 (31.8)	1950 (55.4)	4000 (113.6)	11160 (316.9)	22800 (647.5)
210 (64.0)			92 (2.6)	205 (5.8)	320 (9.1)	660 (18.7)	1030 (29.2)	1780 (50.6)	3700 (105.1)	10330 (293.4)	21100 (599.2)
240 (73.2)				190 (5.4)	300 (8.5)	620 (17.6)	970 (27.5)	1680 (47.7)	3490 (99.1)	9600 (272.6)	19740 (560.6)
270 (82.3)				178 (5.1)	285 (8.1)	580 (16.5)	910 (25.8)	1580 (44.9)	3250 (92.3)	9000 (255.6)	18610 (528.5)
300 (91.4)				170 (4.8)	270 (7.7)	545 (15.5)	860 (24.4)	1490 (42.3)	3000 (85.2)	8500 (241.4)	17660 (501.5)
450 (137.2)				140 (4.0)	226 (6.4)	450 (12.8)	710 (20.2)	1230 (34.9)	2500 (71.0)	7000 (198.8)	14420 (409.5)
600 (182.9)				119 (3.4)	192 (5.4)	390 (11.1)	600 (17.0)	1030 (29.2)	2130 (60.5)	6000 (170.4)	12480 (354.4)
Iron Pipe Sizes In Inches (IPS)	**1/2″**	**3/4″**	**1″**	**1-1/4″**	**1-1/2″**	**2″**	**2-1/2″**	**3″**	**4″**	**6″**	**8″**

Table 6

ES-420 6/88
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KOHLER
GENERATORS

KOHLER CO. KOHLER, WISCONSIN 53044

T I Series No. EL-1

TECHNICAL INFORMATION

KOHLER
ELECTRIC PLANTS
World-Wide

ELECTRICAL

BASIC ELECTRICITY

KOHLER CO. - KOHLER, WIS.

CONTENTS

ELECTRICAL

BASIC ELECTRICITY

Electricity or electrical power was not utilized as a major form of work producing energy until the late nineteenth century. The existence of electricity is not, however, a nineteenth century or modern day discovery. The ancient Greeks, in fact, unknowingly discovered electricity in observing that a piece of rough amber would attract and pull tiny flakes of wood and feathers toward it. The word "electricity" is itself derived from the Greek definition of amber.

Through the centuries man continued his studies of the mysteries of electricity. Long before anyone ever heard of electrons or even imagined that the atom existed, certain men had observed and recorded some of the basic laws of electricity. Even with the recent development of the electron theory, these basic laws remain relatively unchanged and still serve as vital contributions to our understanding of electricity. Since acceptance of the electron theory has advanced our understanding of the fundamentals so greatly, a review of this theory is imperative to further study of electricity.

ELECTRON THEORY

The electron theory states that all matter is made up of thousands of minute particles called molecules which are in turn made up of definite numbers of atoms. There are about 100 atom types and the various combination of these create all substances known.

The structure of an atom resembles a miniature solar system. In the center of this system, we have a positive charged nucleus around which revolve negative charges called electrons. The nucleus is composed of both protons and a combination of negative and positive charges called neutrons. The protons are positive charged and the neutrons have a neutral electrical charge. Neutrons are not important from an electrical standpoint but are mentioned as they help explain the stability of the atom's nucleus. Normally the positive charge of the nucleus exactly balances the negative charge of the electrons and the atom is electrically neutral. In solid materials, the nucleus is, so to speak, anchored in place while the electrons are in constant motion or orbit.

It is hard to imagine electron motion unless one remembers that the atom is so infinite in size that even within solid substances the electrons find great void spaces for free travel. If an unbalance is created through the loss of electrons, the atom becomes predominately positive. Its natural tendency in this condition is to restore balance and return to its normal neutral state. Each atom in turn borrows electrons from its neighboring atom thereby creating a flow or current which continues until this neutral state is again achieved.

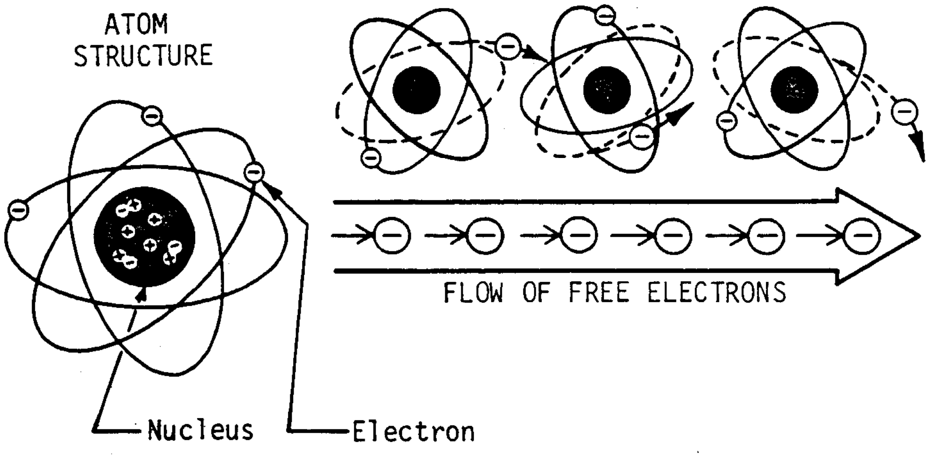


FIGURE 1 - ATOM STRUCTURE - ELECTRON FLOW

The principle of electrical current is based on the atom's ability to readily transfer and regain electrons. The substance of certain materials is such that their atoms will rapidly transfer free electrons. These materials are classified as conductors and include for example metals such as copper and silver. Other atoms hold their electrons very tightly or are said to have bound electrons. Materials containing these atoms are poor conductors and are often used as insulators. These include wood, glass, rubber and other like materials.

ELECTRICAL CURRENT

Electricity is the form of energy which can be generated by various methods from the action of electrons in motion. Electric current is defined as the constant flow of electrons through a conducting path or circuit. Electricity then is thought of as a form of energy while electrical current can be described as the actual harnessing of this form of energy.

Electricity is based on the fundamental law that like electrical charges repel and unlike charges attract one another. The electron being a negative charge will therefore be attracted to a positive charge. Note: This is directly opposite to the conventional theory of flow of electricity. The conventional theory which was adopted long before the Electron Theory was advanced, states that electricity flows from positive charge to negative charge. This difference is mentioned since the conventional idea is more common in everyday usage of electricity.

Current or electron flow takes place within a conductor only when there is a difference in electrical potential and there is a complete circuit or path for electron flow. The moving force that causes electrons to flow from negative to positive charge is called electromotive force or emf. For illustration purposes, the familiar storage battery creates, by chemical action, a difference in electrical potential. The terminals of the battery consist of two separate metal cellplates of differing substance which are immersed in a liquid called an electrolyte. A reaction

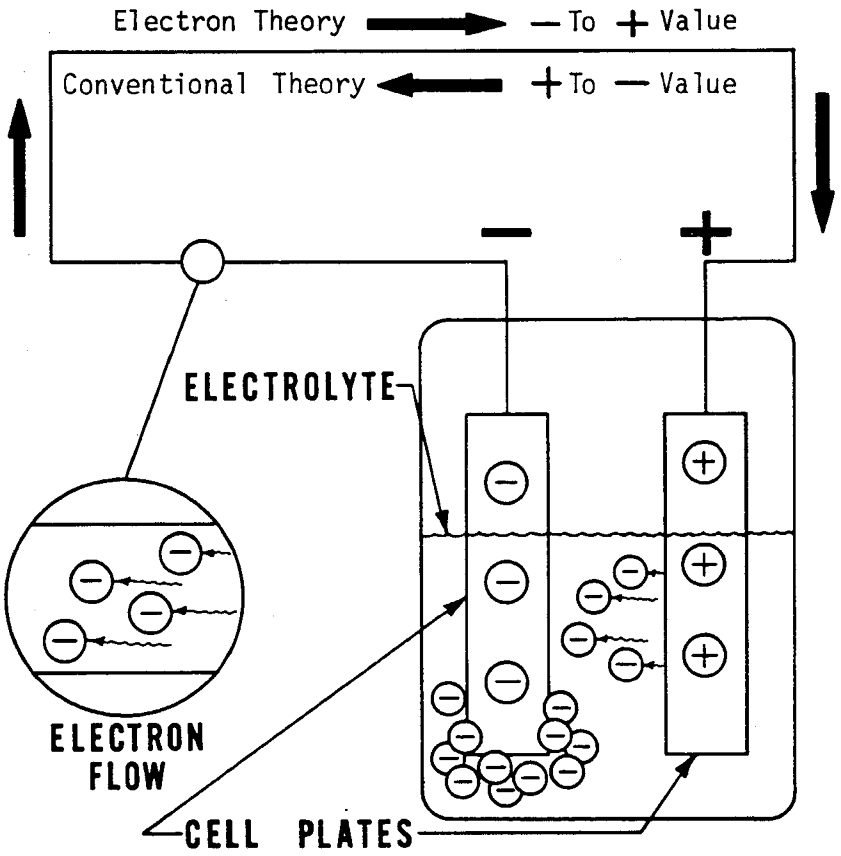


FIGURE 2 - BATTERY PRODUCES DIFFERENCE IN ELECTRICAL POTENTIAL

within the battery changes chemical energy into electrical charges on the cellplates. The electrolyte carries electrons away from one plate and causes a build-up or excess of electrons at the other plate. The plate that has lost electrons becomes positively charged. The electrolyte absorbs excess electrons from the negative plate but will not allow them to return to the positive plate. Connecting the terminals of the two cellplates with a conductor completes the circuit and allows the electrons to flow to the positive terminal. If this difference in electrical potential is maintained, current will continue to flow.

In this illustration we have caused electricity to flow but we have not utilized its energy to produce another form of energy, or we have not put it to work. This could be accomplished by including in the circuit a device which utilizes electricity such as a simple lamp which converts electric energy into light energy.

We have seen that electrical energy can be produced from chemical energy and that electrical energy can be changed into still another form. This is based on another fundamental law that energy can neither be created or destroyed but it can take various forms which can be converted into still other forms. There are six basic ways in which we can convert energy to cause electron flow and thereby create electrical current. They are:

1. Chemical action. Example - Storage battery.
2. Electromagnetic Induction. Example - AC or DC generators.
3. Friction between two bodies. Example - Lightning.
4. Thermoelectric action. Example - Thermocouple.
5. Light. Example - Photoelectric cell.
6. Pressure. Example - Microphone.

We will not go into these various forms of producing electrical current except to mention that they all involve changing energy forms to induce electron flow.

Types of Electrical Current

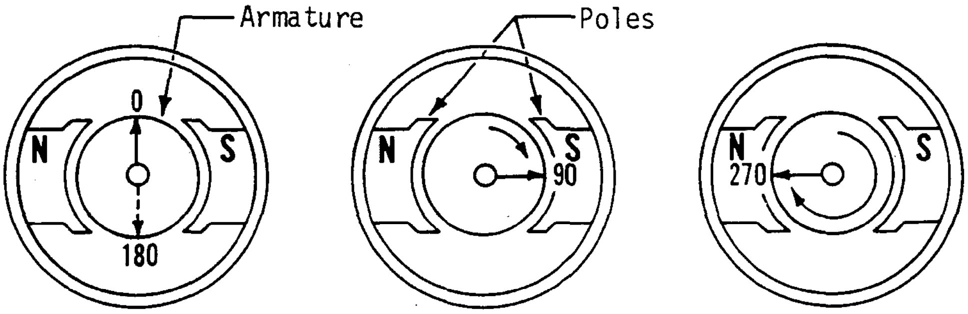
Electrical energy used today is commonly generated in either the form of direct current produced by chemical action and through electromagnetic induction or alternating current which is also produced by electromagnetic induction.

Before proceeding in the discussion of types of currents we need to know a little about the operation of a simple generator. Generators utilize a form of magnetic induction to create flow of electrons.

A simple generator consists of a coil or loop of wire arranged so that it can be rotated in circular motion and cut through a magnetic field consisting of North and South poles. Refering to the illustration, Figure 3, we can see that current alternates according to the armature's position in relation to the poles. At 0° and again at 180° no current is produced. At 90° current reaches a maximum positive value. Rotation to 270° brings another maximum flow of current only at this position current has reversed its polarity and now flows in the opposite direction. All generators produce alternating current in the armature. DC generators are therefore basically AC alternators modified to produce direct current by addition of devices which cause flow to be unidirectional.

Direct Current

Electrons in direct current always flow in a single direction. Current created through chemical action by an automobile battery, for instance, produces a smooth, constant flow of electrons all going in the same direction.



POSITION OF COIL IN A SIMPLE GENERATOR

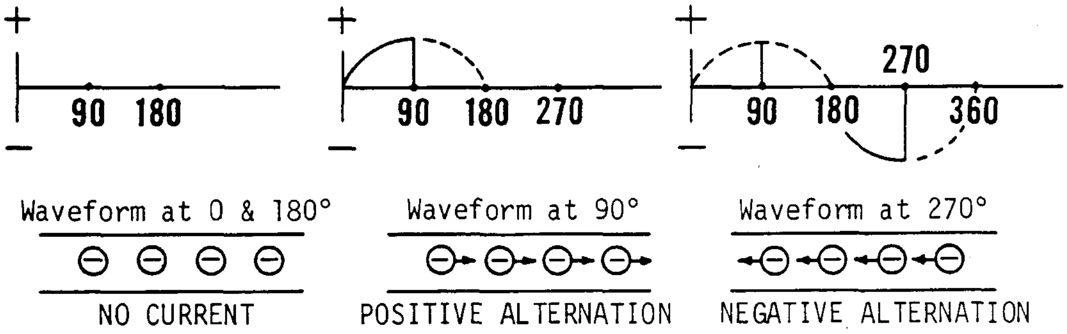


FIGURE 3 - OPERATION OF A SIMPLE GENERATOR

A DC generator also produces a unidirectional flow of electrons, however, a ripple or variation in intensity is evident in its current. This is due to the fact that a DC generator utilizes only the positive alternation of the alternating current. Apparently this current would pulsate from zero to maximum value and return to zero at regular intervals. This is not the actual case since devices are used to smooth out these pulsations so that current is held at a high maximum value with only slight variation in intensity.

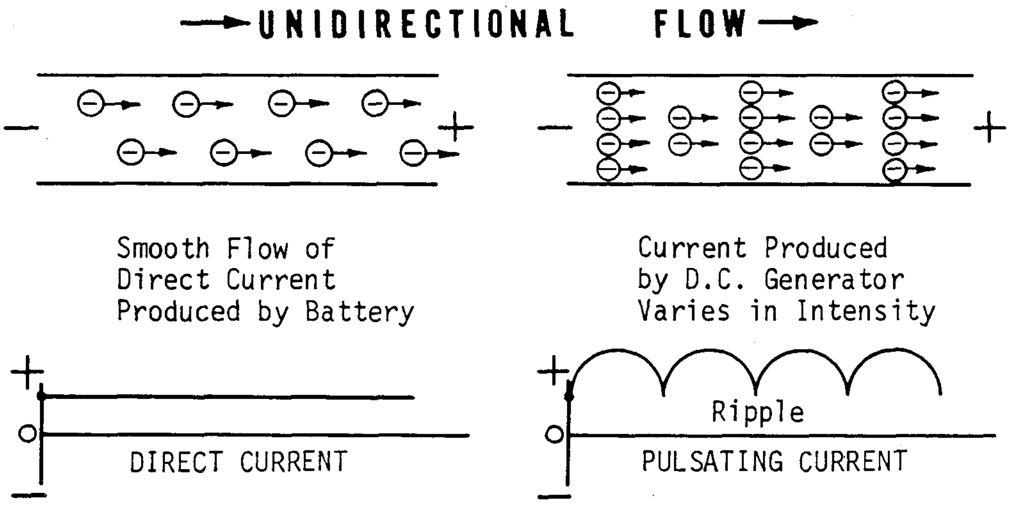


FIGURE 4 - DIRECT CURRENT WAVE FORMS

Alternating Current

With alternating current on the other hand, the electrons flow first in one direction then reverse and move in the opposite direction and repeat this cycle at regular intervals. This reversal is due to a principle of electromagnetic induction. A wave diagram or so called "sine" wave of alternating current shows that the current goes from zero value to maximum positive value, reverses itself and goes to maximum negative value then reverses itself again to return to zero. Two reversals of current such as this is referred to as a cycle. The number of cycles per second is called frequency.

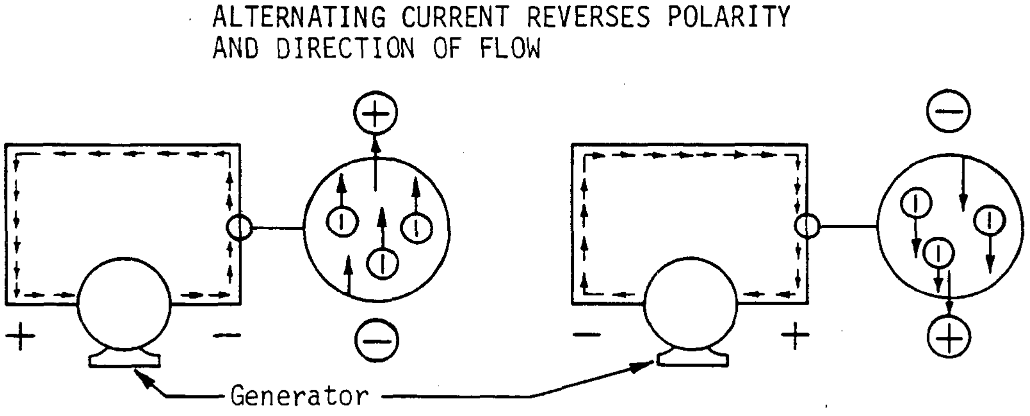


FIGURE 5 - AC REVERSES POLARITY AND DIRECTION OF FLOW

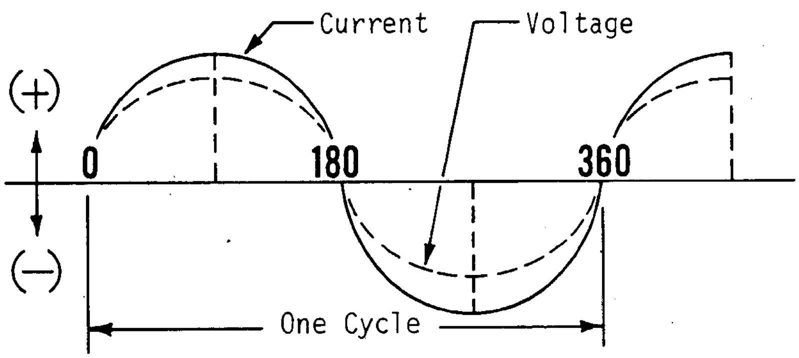


FIGURE 5-A - ALTERNATING CURRENT SINE WAVE

ELECTRICAL UNITS

In the study of electricity and electrical circuits, it is necessary to establish definite units to express quantitive values of current flow, pressure and resistance. The standard electrical units are as follows:

Ampere - Unit of Current Flow

The rate of electron flow in a circuit is represented by the ampere which measures the number of electrons flowing past a given point at a given time, usually in seconds. (One ampere, incidentally, amounts to a little over six thousand--million--billion electrons per second.)

The rate of flow alone is not, however, sufficient to measure electric energy. For example, a placid stream may flow the same gallons per minute as water gushing out of a fire hydrant. The rate of flow in both cases may be the same, but, the pressure or force is much greater in the case of the hydrant. Relating this to electricity, we can have the same amount of current in two wires of greatly varying diameter, however, it is obvious that the pressure must be greater in the smallest wire to obtain the same number of amperes. To measure electric energy accurately, we have to know both the rate of flow and the pressure which causes the flow.

Volt - Unit of Pressure

The volt is the measurement of electrical pressure or the difference in electrical potential that causes electrons to flow in an electrical circuit. If the voltage is weak, few electrons will flow and the stronger voltage becomes, the more electrons will be caused to move. Voltage, then, can be considered as a result of a state of unbalance and current flow as an attempt to regain balance. The volt represents the amount of emf that will cause current to flow at the rate of 1 ampere through a resistance of 1 ohm.

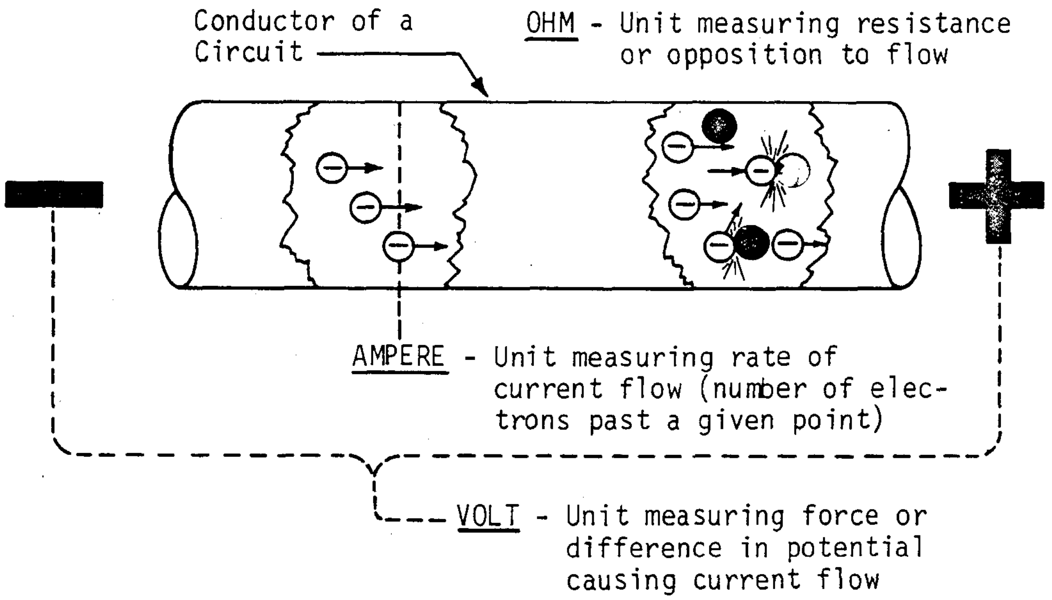


FIGURE 6 - ELECTRICAL UNITS

Ohm - Unit of Resistance

In all electrical circuits there is a natural resistance or opposition to the flow of electrons. When an electromotive force is applied to a complete circuit, the electrons are forced to flow in a single direction rather than their free or orbiting pattern. Utilization of a good conductor of sufficient size will allow the electrons to flow with a minimum of opposition or resistance to this change of direction and motion. Resistance within an electrical current is evident by the conversion of electrical energy into heat energy. The resistance of any conductor depends on its physcial makeup, its cross sectional area, its length and its temperature. As the temperature of a conductor increases, its resistance increases in direct proportion. One ohm expresses the resistance that will allow one ampere of current to flow when one volt of electromotive force is applied. Resistance applies to all DC circuits and some AC circuits. Other factors affect rate of flow in most AC circuits. These factors are known as reactance and are described later.

Ohm's Law (Measuring Units)

In any circuit through which a current is flowing, three factors are present.

a. The pressure or potential difference (volts) which causes the current to flow.
b. The opposition or resistance of the circuit (ohms) which must be overcome before the current can flow.

c. The current flow (amperes) which is maintained in the circuit as a result of the pressure overcoming resistance.

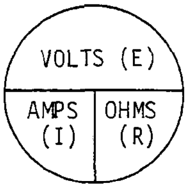
A definite and exact relation exists between these three factors thereby the value of any one factor can always be calculated when the values of the other two factors are known. Ohm's Law states that in any circuit the current will increase when the voltage increases but the resistance remains the same, and the current will decrease when the resistance increases and the voltage remains the same. The formula for this equation is Volts = amperes x ohms ($E=IR$).

To use this form of Ohm's Law, you need to know the amperes and the ohms, for example, how many volts are impressed on a circuit having a resistance of 10 ohms and a current of 5 amperes? Solution: $E=5 \times 10 = 50$ volts.

The formula may also be arranged to have amperes the unknown factor, for example, Amperes = volts divided by ohms.

To have ohms the unknown factor, arrange the formula in this manner. Ohms = volts divided by amperes.

The circle diagram provided can be used as an aid to remembering these equations. To use this diagram, simply cover the unknown factor and the other two will remain in their proper relationship. This figure should be used as a short cut only and not as a substitute for understanding the basic equations.

MEASURING UNIT -- SYMBOL	EQUATIONS	RELATION OF UNITS*
CURRENT FLOW - AMPERES = I	$\text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$	
PRESSURE - VOLTS = E	VOLTS = AMPERES x OHMS	
RESISTANCE - OHMS = R	$\text{OHMS} = \frac{\text{VOLTS}}{\text{AMPERES}}$	
CURRENT FLOW IN A CIRCUIT IS DIRECTLY PROPORTIONAL TO THE PRESSURE AND INVERSLY PROPORTIONAL TO THE RESISTANCE.		

* When two values are known, cover the unknown to obtain the formula.

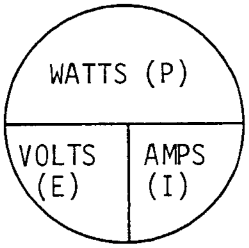
FIGURE 7 - ELECTRICAL UNIT EQUATIONS

Watts - Unit of Power

We measure electric power in watts. One watt is equal to a current of one ampere driven by a pressure of one volt. For the larger blocks of power we use the term kilowatt for one thousand watts. There is a definite relationship between electric power and mechanical power. One horsepower equals seven hundred and forty-six watts of electrical energy. (746)

Since power is the rate of doing work, it is necessary to consider the amount of work done and the length of time taken to do it. The equation for calculating electrical power is P = E x I or Watts = Volts x Amperes. Using this equation to find the power rating of a 120 volt, 30 ampere generator, we would come up with the following: P = 120 x 30 = 3,600 watts. The power equation can also be expressed in different forms. We can use it to find amperes when watts and volts are known. An example of this would be: Amperes = Watts divided by Volts. This equation is used frequently in figuring the current of any DC electric plant or any appliance such as electric heater or light bulb rated in watts. We can combine the ohm equation with the watt equation to form other useful equations in determining power factor of circuits.

WATTS - THE MEASURING UNIT OF ELECTRICAL POWER



EQUATIONS

$$\text{WATTS} = \text{VOLTS} \times \text{AMPERES}$$

$$\text{AMPERES} = \frac{\text{WATTS}}{\text{VOLTS}}$$

$$\text{VOLTS} = \frac{\text{WATTS}}{\text{AMPERES}}$$

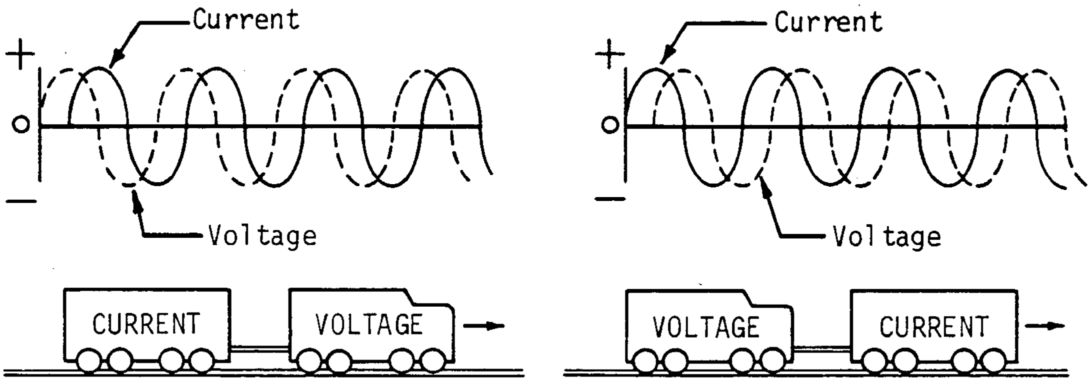
FIGURE 8 - WATT EQUATIONS

Reactance in AC Current

In DC the only opposition to current flow to be considered is resistance. This is also true in AC current if only resistance type loads such as heating and lamp elements are on the circuit. In such cases the current will be in phase with the voltage--that is, the current wave will coincide in time with the voltage wave. Voltage and current are seldom, however, in phase in AC circuits due to several other factors which are inductive and capacitive reactance.

Inductive reactance is the condition where current lags behind voltage. Magnetic lines of force are always created at right angles to a conductor whenever current flows with-in a circuit. An emf is created by this field only when current changes in value such as it does constantly in alternating current. This magnetic field induces electromotive forces which influences current to continue flowing as voltage drops and causes voltage to lead current. If a conductor is formed into a coil, the magnetic lines of force are concentrated in the center of the coil. This greater density causes an increase in magnetically induced emf without increasing current. Coils, therefore, cause inductive reactance. This condition is also caused by an induction motor on the circuit which utilizes the current's magnetic field for excitation.

Capacitive reactance is, on the other hand, the condition where current leads the voltage. Capacitance can be thought of as the ability to oppose change in voltage. Capacitance exists in a circuit because certain devices within the circuit are capable of storing electrical charges as voltage is increased and discharging these charges as the voltage falls.



Current Lags Voltage

INDUCTIVE REACTANCE

Current Leads Voltage

CAPACITIVE REACTANCE

FIGURE 9 - REACTANCE SINE WAVES

POWER FACTOR

Unity power factor applies to the circuits where current and voltage are in phase. This is also referred to as a power factor of 1. The true power (watts) of a unity power factor circuit is easily calculated as a product of amperes times volts (divided by 1000 for KW).

When out of phase conditions prevail, as is the usual case in AC circuits, the product of amperes times volts reveals the apparent power of the circuit rather than the true power. KVA represents kilovolt-amperes and describes apparent power while KW is used to describe true power in AC circuits with inductive or capacitive reactance. An analogy relating mechanical work to electrical power may help explain the reason for apparent and true power ratings of reactance type AC circuits.

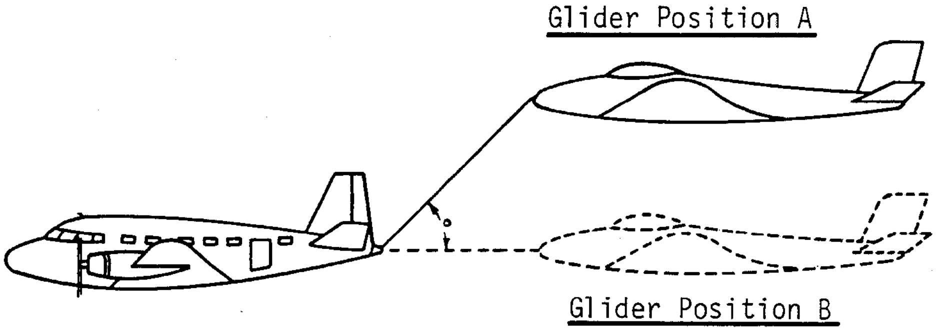


FIGURE 10 - MECHANICAL WORK - POWER FACTOR ANALOGY

Referring to Figure 10, we see an airplane towing a glider. Assume that the tow plane must, for some reason, pull the glider in Position A. In this position, the tow cable is at an angle of 45°. The force applied by the tow plane is then at an angle to the direction of motion of the glider.

It is obvious that more force must be exerted in Position A to do the same amount of useful work that would be accomplished in Position B where no angle exists and force and motion are in the same direction.

A situation similar to that shown in the foregoing analogy presents itself in inductive or capacitive AC circuits. In these circuits more power must be supplied than can actually be utilized because an angle similar to the one in the analogy exists between voltage and current. Since current either leads or lags voltage by a number of degrees in time, they never reach their corresponding maximum values at the same time within these circuits.

Referring to the 45° inductive reactance sine wave illustrated in Figure 10-A, we see that at point B (or 90° in time) voltage has reached its maximum value while current has approached but not quite reached its maximum value. If we calculate the power in the circuit at this point (or any other point for that matter), the product of volts times amperes will not indicate the actual or true power for while voltage is at its peak value, current is at less than its maximum value. In other words, this reveals only the apparent power.

To determine the true power, the number of degrees that current is out of phase with amperes must be applied as a correction factor.

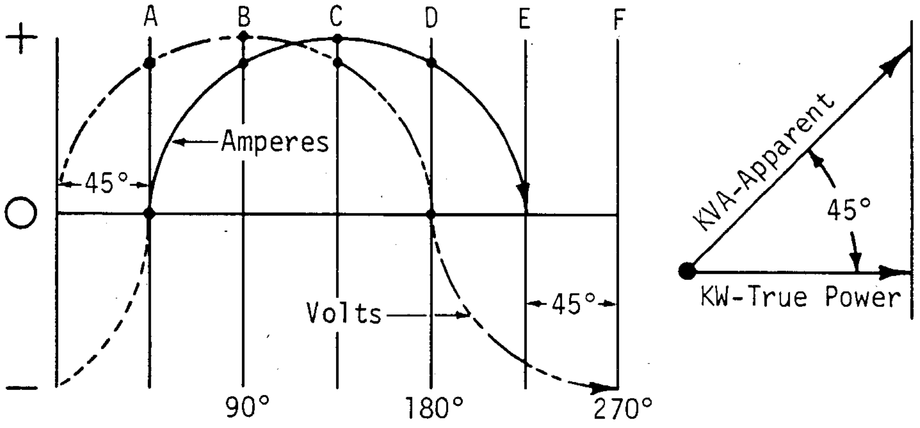


FIGURE 10-A - POWER FACTOR DETERMINED BY DEGREE VOLTS "OUT OF PHASE" WITH AMPERES

This correction factor is called power factor in AC circuits and it is the cosine of the phase angle. The cosine of any angle is usually listed in math and electrical handbooks. The cosine of the angle of 45° would be 0.707 or electrically a power factor of 0.707.

The triangular representation shown in Figure 10-A can be used to find the apparent (KVA) and true (KW) ratings of a 240 volt, 55 ampere, single phase generator. Since KVA is the product of volts times amperes, KVA in this case will equal 240 x 55 divided by 1000 or 13.2. The triangle shows an angle of 45° between volts and amperes. The power factor would be the cosine of this angle or 0.7.

The true power of this generator can now be calculated as the product of KVA (13.2) times power factor (.7). The true power of the generator will, therefore, be 9.24 KW. At .8 power factor, this same generator could be rated at 10.56 KW so we see that the higher the power factor - the greater the real power (KW) of the generator.

Normally the rating of an AC generator is stated at "unity" power factor for pure resistance type loads. This rating is also frequently stated at .8 power factor to accommodate average reactance type loads. The power factor rating of a generator must at least match the power factor of the load applied. In most cases, it is not safe to assume that a load is, in fact, average and that the generator's .8 power factor rating is sufficient to carry the load. The actual power factor of the load should be determined.

There are numerous ways in which the power factor of a circuit can be determined, however, a discussion of the various methods becomes too involved to adequately cover in our study of basic electricity.

ELECTRICAL CIRCUITS

We have learned that in order to have flow of electrical current, a circuit must form a complete conducting path from the positive to the negative terminal of the source electromotive force. There are only two basic types of circuits that can be used in putting electrical energy to work. Understanding these two types of circuits helps explain the seemingly complex nature of electrical circuitry. The two basic types are series and parallel circuits. Most complex systems consist of a combination of series and parallel circuits.

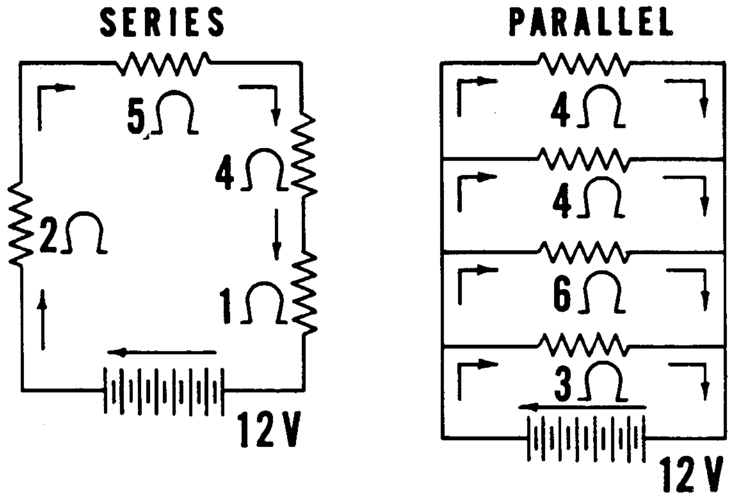


FIGURE 11 - BASIC CIRCUITS

Series Circuit

In a series circuit, current is provided with only one path in which to flow. A break anywhere in the circuit stops current in the entire system. Electrical apparatus is connected in tandem in a series circuit and current in every component is exactly the same as every other component. The basic principles of electrical current applies to a series as follows:

Resistance

The total resistance in the series circuit is equal to the sum of the individual resistors.

RT = R1 + R2 + R3 + RY.

Voltage

The voltage drop across each resistor may be found by using the formula E = IR. The sum of the separate voltage drops if each resistor is equal to the total voltage. Voltage drop is loss of voltage due to energy being converted to another form, such as heat loss in resistors.

Amperes

The current in the circuit is equal at every point for example.

$$I = \frac{E}{\text{Total Resistance}}$$

The laws concerning series circuits may be summarized as follows:

1. The current is the same in every part of the series circuit.
2. The total resistance of several resistances in series is the sum of the separate resistances.
3. The total voltage across several resistances in series is equal to the sum of the voltage across the separate resistances.

Parallel Circuit

Current in a parallel circuit is provided with two or more paths or branches in which to flow from a single source emf. Elements such as resistors within the individual branches are completely independent of others in separate branches. That is, they are not influenced by values of others. If a short circuit occurs with any branch connection, the circuit and other components of the system may continue operation. The basic laws governing electricity affect parallel circuits in the following ways:

Resistance

In a parallel circuit, total resistance is less than the resistance of any of the paths or branches singlely. To find the total resistance of a parallel circuit, we use a reciprical of resistance. For example:

$$\frac{I}{R} = \frac{1}{r} + \frac{1}{r_2} + \frac{1}{r_3} \qquad \frac{I}{R} = \frac{1}{10} + \frac{1}{20} + \frac{1}{60}$$

$$\frac{I}{R} = \frac{6 + 3 + 1}{60} = \frac{10}{60} = \frac{1}{6} \text{ or 6 ohms}$$

Voltage

The voltage applied by the source to each component in a parallel circuit is the same as the source voltage, and the same as every other component in the circuit.

Current

The total current through the branches is the sum of the currents through the individual parts. The joint resistance of the parallel circuit is equal to the voltage divided by the total current.

Conditions Affecting Circuits

In discussing electrical circuits certain terms are used to describe various conditions which adversely affect operation of circuits. Some of the more common terms are as follows:

1. An open circuit is simply an incomplete circuit.
2. A partially open circuit is one in which a high resistance has developed due to loose connections, corroded connections or partially broken wires. Due to the increase in resistance in the circuit, the current flow will decrease.
3. A short circuit is a condition where there is an abnormal decrease in the resistance across some part of it.
4. A partial short circuit is a condition where only slight contact is made between the positive and negative sides of the circuit and only a small part of the current will by pass.

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WIRING SYSTEMS

By varying the placement, connection and number of coils within a generator, we can alter its voltage output and phase relationship. To understand wiring systems, it is necessary to know something about the construction of a simple generator.

A simple revolving armature generator would consist of a coil or loop of wire arranged so that it can be rotated in circular motion through a magnetic field consisting of north and south poles. Rotating the coil causes magnetic lines of force to be cut which in turn produces electrical current. Collector rings or commutators are used to pick up electricity generated by the generator's armature which is rotated through a magnetic field. Brushes which are directly connected to a completed electrical circuit ride on and pick up electricity from the collector rings.

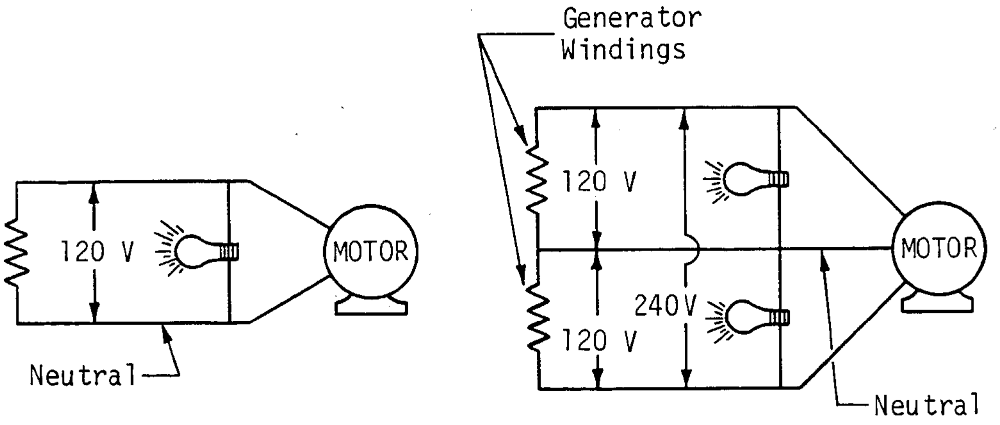
Voltage then is determined by the number of coils provided within the armature. Phase is determined by the number of separate armature windings in a generator. In other words, a three phase generator would have three separate windings connected on the same shaft.

The most common types in use today are single phase, two and three wire systems and three phase, three and four wire systems. We shall discuss the types used with Kohler Electric Plants here.

SINGLE PHASE SYSTEMS

Single phase -- two wire, 120 volt systems are commonly used in homes and many small business establishments since most appliances and small tools are rated for 120 volt AC operation. Two wires are used to carry current and connect this type of power.

Single phase -- three wire, 120/240 volt systems are perhaps the most popular today in combined lighting and fractional horsepower applications. This type of system provides three separate sources of power at two different voltages. This is accomplished by two separate 120 volt windings on a generator or by adding a center tap to a 240 volt generator. Single phase voltages add up like inches on a foot rule. Either end of the rule is just six inches from the six inch mark, but it is still twelve inches from one end to the other. Likewise, if we ground the center tap of a 240 volt winding, we can obtain 240 volts for motor loads and 120 volts for lights.



120 VOLT 2-WIRE

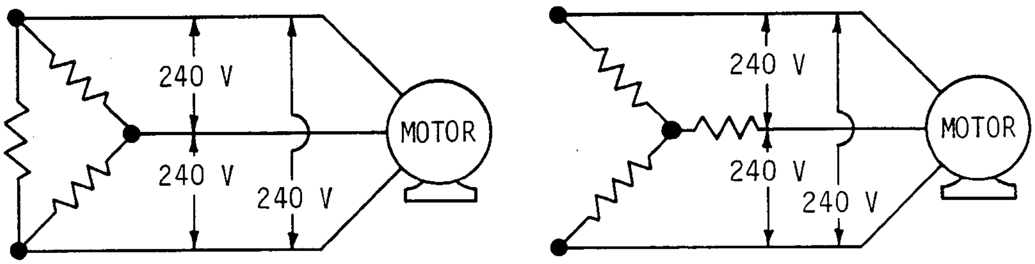
120/240 VOLT 3-WIRE

FIGURE 1 - SINGLE PHASE WIRING SYSTEMS

A generator or transformer connected in this manner supplies only half its capacity in each section of the winding, therefore, 120 volt loads must be approximately evenly divided between the 120 volt legs. If a 240 volt load is connected, deduct the 240 volt power used from the total power capacity. The remainder should be equally divided and taken from the 120 volt sources.

THREE PHASE SYSTEMS

Three phase -- three wire, 240 or 480 volt systems. If three identical generators are connected to the same shaft so that the voltages are equal in magnetude and symetrically displaced in time phase from each other, the combined output is a three phase source. These voltages, when equally displaced, are 120 electrical degrees apart and independent from each other. The separate voltages are therefore available from the windings of each of the three generating sections. A three phase, three wire, generator is connected in either Delta or Wye forms as illustrated.



DELTA CONNECTION

WYE CONNECTION

FIGURE 2 - THREE PHASE, THREE WIRE SYSTEMS

Three phase -- four wire, 120/208 volt systems. If a central or neutral point is established in a Wye connection, the system becomes a three phase, four wire system. The fourth wire or neutral is at a point midway between the other three lines. This system is used to accommodate both light and motor loads.

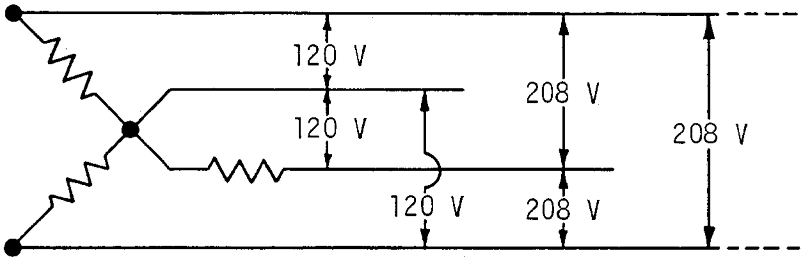


FIGURE 3 - THREE PHASE, FOUR WIRE 120/208 VOLT SYSTEMS

Three phase -- four wire Delta, 120/240 volt systems. This system is obtained by adding a center tap along one of the sides of a three phase Delta. This can be simply illustrated by a triangle containing three 240 volt legs. By adding a center connection to one of the legs, we split the voltage midway in this leg to two 120 volt sources.

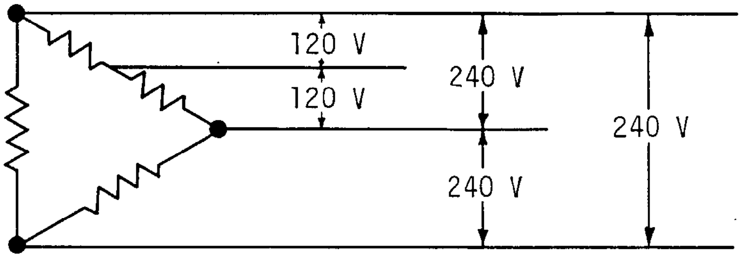


FIGURE 4 - THREE PHASE, FOUR WIRE, 120/240 VOLT SYSTEMS

Three Phase Power Formula

In figuring three phase power we have to consider another factor. This factor is the square root of 3 which is 1.73. Calculation of power in a three phase system could be done using the following formula:

Watts = 1.73 Volts x Amperes x Power Factor

or P = 1.73 (PF).

$$KVA = \frac{1.73 \text{ Volts x Amperes}}{1000}$$

$$\text{or } KVA = \frac{1.73EI}{1,000}$$

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CONTROL OF ELECTRICITY

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CONTROL OF ELECTRICITY

The exacting degree of electrical control achieved today is possible only through utilization of a wide variety of devices such as transformers, rheostats, resistors, capacitors, etc. Development of control devices such as these would not have been feasible were it not for the knowledge of the electron and its characteristics. In this bulletin we will discuss some of the more common devices and how they are used to control electricity.

Transformers

Control of electricity can be achieved through the use of transformers which are devices used to increase (step up) or decrease (step down) voltage. A typical transformer consists of a metal core around which are wrapped two separate coils of wire called the primary and secondary coil. The coils are placed opposite to each other so that voltage applied to one coil will be transmitted to the other through the process of electromagnetic induction. By varying the number of turns in the coils induced voltage can be either stepped up or down as desired. In the stepped up transformer, the secondary coil is provided with more turns than the primary. Power applied to the primary coil generates a magnetic field which cuts across the secondary coil which in turn amplifies or steps up voltage in direct ratio the number of additional turns of wire that it has. In step down transformers, the secondary coil has fewer turns and therefore reduces voltage accordingly. The familiar engine ignition coil is a good example of a step up transformer.

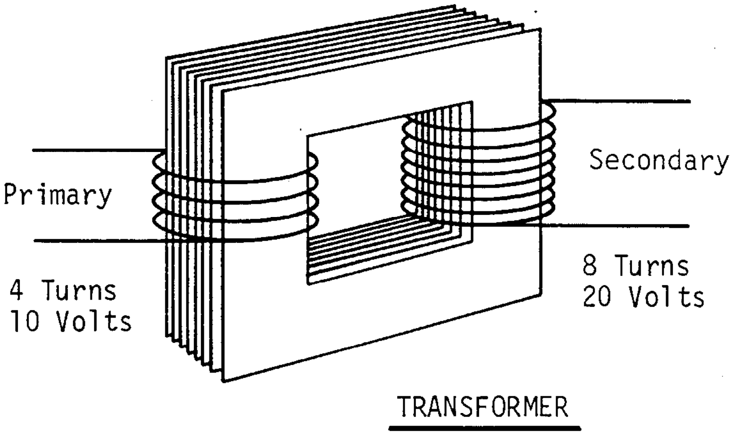

FIGURE 1 - BASIC TRANSFORMER

Resistors

A resistor is a device inserted in a circuit to introduce resistance and thereby limit amount of current flow.

A rheostat can be classified as a simple type of variable resistor. In this device, current is directed through a number of coils where a certain amount of electrical energy is lost through conversion to heat energy. Control of resistance and of electricity is therefore achieved by varying the number of coils within which current is allowed to flow. The greater the length of a conductor, the greater is its resistance and therefore the greater the number of coils, the greater the resistance.

Fixed resistors, on the other hand, can consist of either coils of wire or conductor of smaller diameter or of material of differing conducting value than the rest of the circuits conductor. Since resistance also depends on a conductor's physical properties and cross sectional area, these factors are utilized in construction of a fixed resistor.

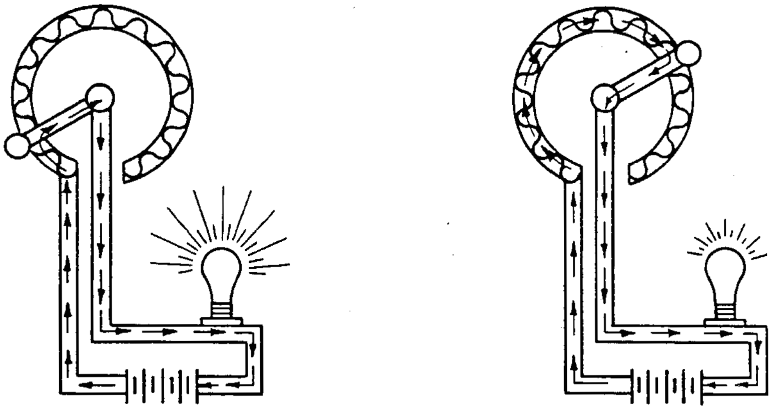

FIGURE 2 - RHEOSTAT - VARIABLE RESISTOR

Capacitors

Capacitors are sometimes referred to as condensers--they are, however, one and the same thing. Capacitors are electrical devices used to store energy within a circuit. A simple capacitor consists of two metal plates of good conducting ability separated by an insulator called a dielectric. The capacitor's ability to store energy is determined by the area and material of the plates, the distance between the plates and the type of dielectric used.

In operation, the plate connected to the negative terminal of the source emf receives an excess of electrons and therefore builds up a negative charge. The dielectric will prevent appreciable flow of electrons between the plates. The electrons bound to the atoms within the dielectric are repelled and distorted out of their normal orbit, that is, they move away from the like charges of the negative plate and move closer to the other plate. In so doing, they force electrons out of this plate causing it to become positive in charge. A difference in electrical potential or voltage is therefore built up between the plates.

A capacitor in a DC circuit will allow current to flow only while the plates build up charge which is only momentarily. After the plates are fully charged, the capacitor then becomes an effective open circuit in DC. In AC circuits, the constant reversal of polarity causes the plates to charge in one direction, discharge and then charge in the opposite direction at regular intervals. In AC then, even though current does not actually flow through the dielectric, there is a constant flow to and from the plates.

Capacitors cause current to lead voltage and are used in AC circuits to neutralize the undesirable effects of laging current or inductive reactance which causes poor efficiency and can overload the power source. Capacitors are also used in some cases to filter or block DC current from entering a circuit.

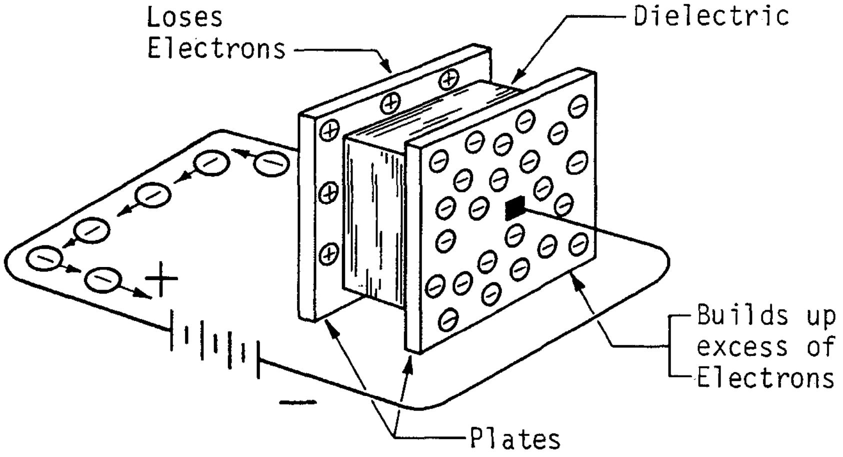

FIGURE 3 - CAPACITOR STORES ENERGY

Rectifiers

A rectifier is a device designed to change alternating current to pulsating direct current. They are constructed so that they offer low resistance to current flow in one direction but very high resistance to flow in the opposite direction. The types of rectifiers are so numerous that we will not go into the operation here except to mention that they permit current to flow only while on the positive alternation and not on the negative alternation. The current emitted from a rectifier is therefore a pulsating direct current.

Voltage Regulators

Voltage regulators are designed to maintain the output voltage of a power source at a constant predetermined level as voltage fluctuates when load on the circuit increases or decreases. Fluctuation is a common occurance especially where motors are started and stopped frequently. A good example of this would be the motor driving an elevator in an office building.

There are many types of voltage regulators with a varying degree of response and accuracy. One type frequently used is the electromechanical voltage regulator which employs AC coils as voltage sensing elements, resistors and mechanically operated contacts to vary excitation. Another common type is the static regulator which employs inductors, capacitors, rectifiers and transformers to supply DC excitation directly to the field of the generator and thereby control the output voltage of the source.

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MEASURING ELECTRICITY

Proper diagnosis of electrical systems can often be accomplished through utilization of several instruments familiar to all electricians. Connecting meters properly and understanding their readings enables the electrician to determine if a system is performing properly, or if adjustment or replacement of components is needed. The common types of instruments are the Ammeter, Voltmeter, Ohmmeter and Wattmeter.

Most meter movements are of the moving coil type which consists of a permanent horseshoe magnet and a movable coil. Current flowing through the movable coil reacts with the permanent magnet causing the coil to rotate against a light spring tension. The movement of the coil is in proportion to the amount of current flowing in the windings. A pointer attached to the coil moves across a calibrated scale indicating the amount of current flowing in the coil. The accuracy of the readings will depend upon the accuracy of the meters used.

The same meter movement may be used for either a voltmeter or ammeter. It becomes a voltmeter when connected in series with the proper amount of external resistance and it becomes an ammeter when connected with the proper shunts.

Ammeters

Ammeters are connected in series with the circuit in which current is to be measured. Where necessary, external shunts are provided so that only a small proportional part of the total current passes through the instrument. Since the current value of the circuit should be the same after the meter is inserted in series as it was before the meter was hooked up, it follows that ammeters must have a low resistance between terminals.

FIGURE 1 - TYPICAL TEST INSTRUMENTS

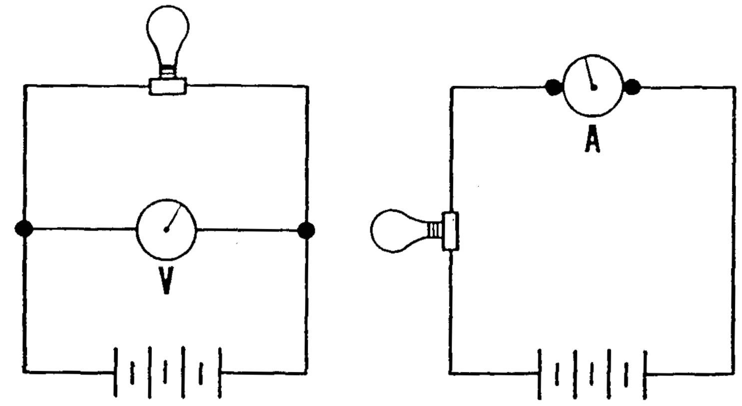

FIGURE 2 - PROPER AMMETER AND VOLTMETER HOOK-UP

Voltmeters

Voltmeters are connected across or to put it another way, in parallel with the circuit. They must have a very high resistance so that the small amount of current they will take will not disturb the circuit. The voltage of a circuit should be essentially the same after the voltmeter is hooked up across the circuit as it was before. If the voltmeter does not have a sufficiently high resistance, this will not be true. The voltmeter is never connected into a line, it is connected across the load.

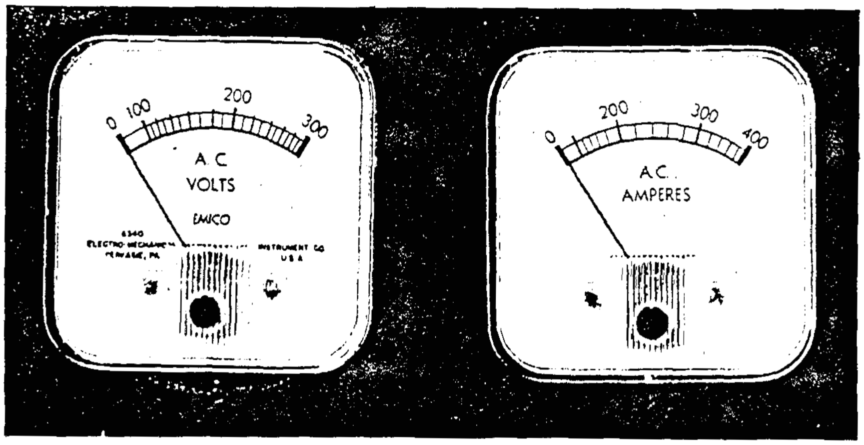

FIGURE 3 - METERS USED ON KOHLER CONTROLLERS

Ohmmeter

An ohmmeter is the instrument used to measure the resistance within a circuit. Since the ohmmeter measures only resistance, the power to a circuit must be disconnected before the resistance reading is taken, also disconnect all parallel circuits.

Wattmeter

The wattmeter is the instrument used to measure power in electrical circuits. The wattmeter scale is calibrated in watts and since power (watts) is determined by voltage times amperes, the wattmeter has four terminals, two for measuring current and two for voltage. The voltage terminals are connected across a circuit while the current terminals are connected in series with the circuit current. Two terminals, one voltage and one current are marked ±. These terminals must be connected at the same point in a circuit.

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MAGNETISM

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MAGNETISM

Magnetism is one of the natural forms of energy -- it is an invisible force that can be seen only in the effect it produces. It is closely related to electricity but not the same thing. Magnetism can be utilized to produce electricity and electricity can be used to produce magnetism. A study of one must therefore include a study of the other. Much about magnetism is unknown, that is, it cannot be explained by our present knowledge, however, without knowing exactly what magnetism is, certain behavior patterns of magnetism are known and application of these known factors has led to the development of generators, motors and numerous other apparatus that utilize magnetism to produce and utilize electrical energy.

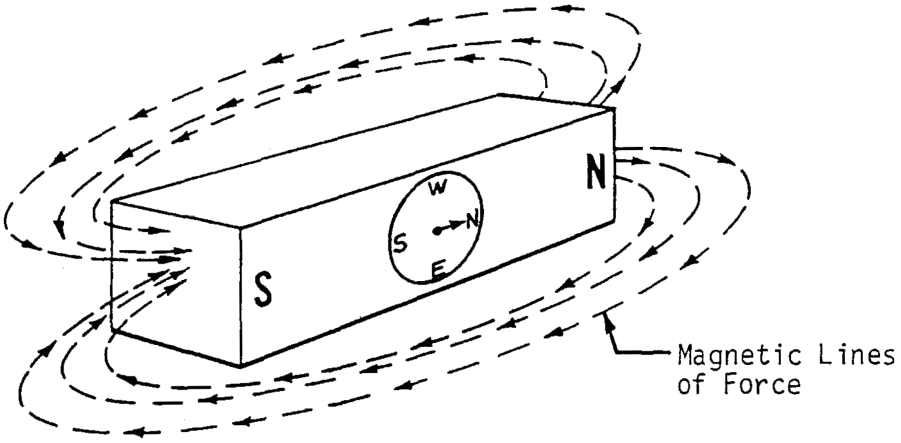

FIGURE 1 - MAGNETIC LINES OF FORCE

The space surrounding a magnet is permeated by magnetic lines of force. Magnetism is concentrated at two points -- the north and south poles. The invisible lines of force, called flux, are directed away from a magnet at its north pole, travel in a loop and re-enter the magnet at its south pole. Magnetic force lines form definite patterns which vary in density according to the strength of the particular magnet. These lines of force never cross one another. The region surrounding a magnet in which its magnetic influence is effective is referred to as a magnetic field.

MAGNETS

The Greeks are credited with the discovery of the natural magnet. A rock, common to the area surrounding the city of Magnesia, was discovered to have the ability to attract and pick up other bits of iron. This rock was actually a type of iron oxide which is now called magnetite. It is believed that the Chinese were the first to put natural magnets to use. The word lodestone, which is commonly used to describe a natural magnet, is from the Chinese, meaning leading stone. They observed that one end of a lodestone, when suspended on a string, would always point in the direction of the North Star and they used this characteristic to guide them in their travels more than two thousand years ago.

Natural magnets are classified as substances which possess natural magnetic properties. The earth itself is thought of as a large natural magnet. Artificial magnets are materials in which magnetic properties can be electrically induced. These include metals such as tungsten, chromium, cobalt and alloys such as alnico.

Characteristics of all magnets are:

1. Like poles repel while unlike poles attract and these react in a definite direction along the magnetic lines of force.
2. The direction of every line of force is assumed to be such that it passes out of the north pole, makes a complete circuit through the surrounding space, re-enters the magnet at its south pole, then completes the circuit.
3. Magnetic induction causes an artificial magnetic substance to become a magnet when it is brought under the influence of a magnetizing force.

Retentivity is the power of a magnetic substance to retain its magnetism when the magnetizing force is removed. On the other hand, permability of a substance is an indication of the ease with which magnetic lines of force can be established in the substance.

ELECTROMAGNETIC FIELDS

All current carrying conductors have a magnetic field surrounding them and this field is always at right angles to the conductor. The presence of this field may be demonstrated by placing a compass close to a conductor carrying electrical current. The needle will move to a right angle with the conductor. This field differs from that of a regular magnet in that there are no magnetic poles in the conductor at which the lines of force can enter or leave. The greater the current flow, the stronger the magnetic field produced. The increase in the number of lines of force is in direct proportion to the increase in the current and the field is distributed along the full length of the conductor. The direction of the lines of force around the conductor may be determined by a simple rule when the direction of the current flow is known. This rule is known as the right hand rule for determining the direction of lines of force around a straight conductor.

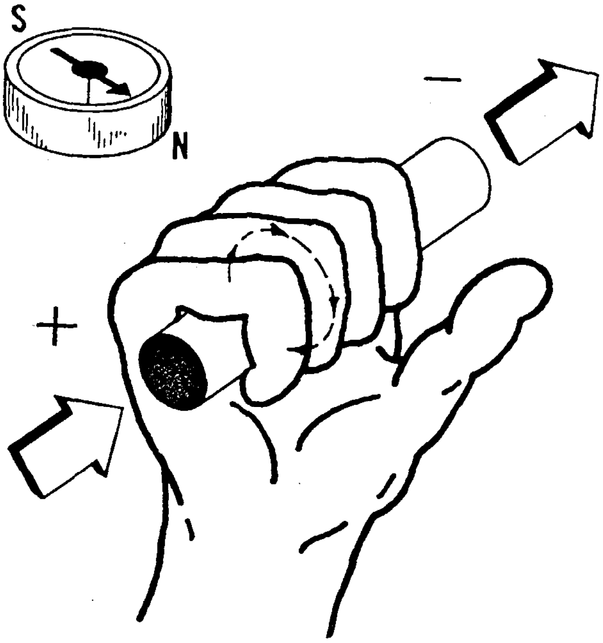

FIGURE 2 - RIGHT HAND RULE

The right hand rule is based on the conventional current theory which assumes that current flows from positive to negative rather than the electron theory which states that current flow is from negative to positive. To apply this rule, put your right hand around a conductor with the thumb pointing in the direction of current flow, as illustrated in Figure 2. The fingers will also be pointing in the direction of the lines of force. A compass may be used to first determine the direction of the lines of force and the right hand rule applied to find the direction of current flow.

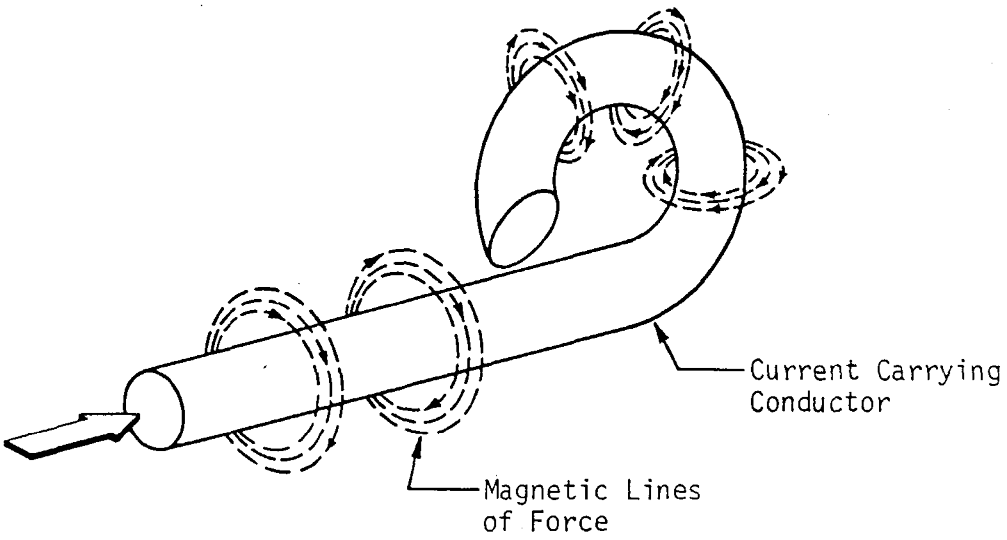

FIGURE 3 - ELECTROMAGNETIC FIELDS

If the current carrying conductor is formed in a simple loop, all the lines of force around the conductor must pass through the inside of the loop. The lines of force at the inside of this loop are more confined which results in a greater density and a much greater magnetic effect without an increase in current flow. Current flow in the loop creates a magnetic field similar to that of a permanent magnet with opposite poles on opposite sides of the loop. This electromagnetic field created by current flow is utilized in many ways.

Combined Magnetic Fields

Certain physical effects of these magnetic lines of force are evident in the flow of electricity within circuits. In the simple two wire parallel circuit, in which one wire carries the current to the load and the other the return current, the lines of force are clockwise around one and counterclockwise around the other as shown in figure 4, section A. This creates a condition of interreaction between the lines of force which in turn causes the wires to actually move away from one another. The force developed by this interaction can be tremendous in circuits with high current flow. These are put to work electrically, for example, one type of electric motor utilizes the interaction of opposing force to create the torque necessary for rotation of its rotor.

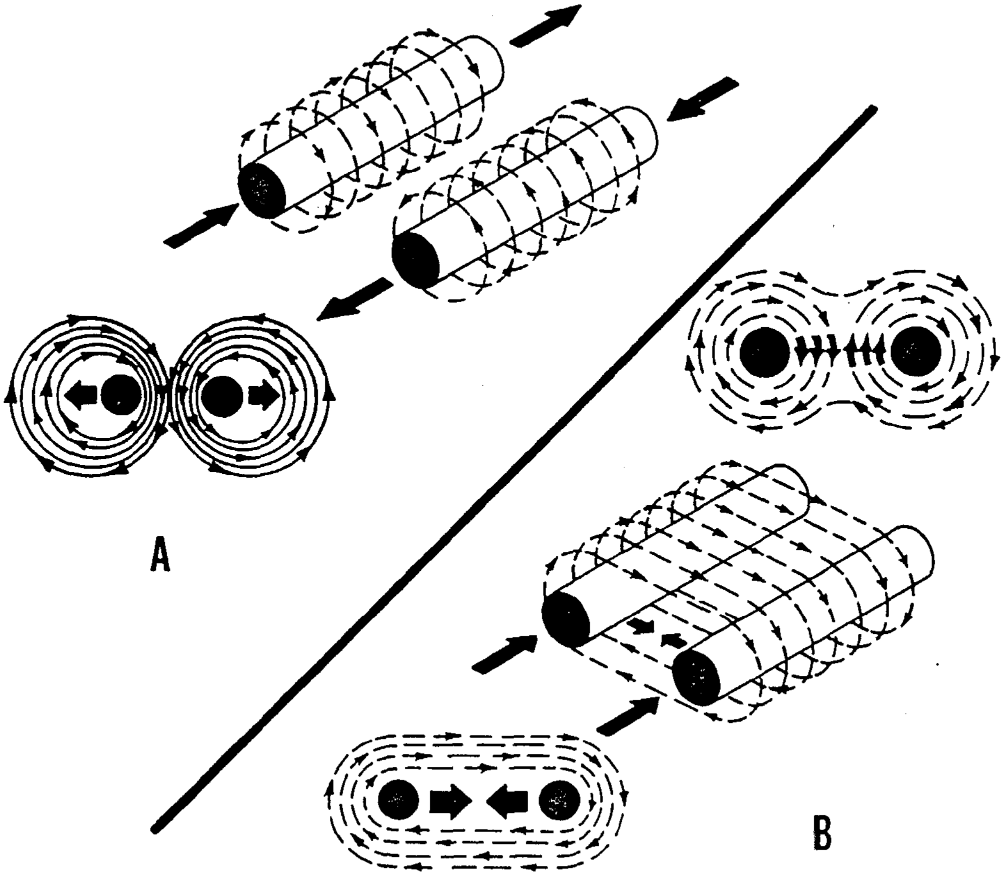

FIGURE 4 - COMBINED AND OPPOSING MAGNETIC FIELDS

Opposing Magnetic Fields

Current flowing in the same direction in parallel circuits creates the magnetic effect of opposing magnetic fields. This is illustrated in Figure 4, Section B. In this situation, lines of force are in opposite direction to each other. Toward the center, the lines of force cancel each other out and produce an unbalanced field. To relieve this unbalance, the conductors tend to move together and in so doing, form a single electromagnetic field that has twice the number of lines of force as each conductor alone. By increasing the number of conductors, a greatly expanded magnetic field can be obtained such as those used in the field coils of a generator or an ignition coil.

Magnetic Field of a Coil

When a conductor is formed into a coil, all the lines of force enter at one phase of the loop and leave at the other as we have mentioned earlier. This creates a north pole on one phase and a south pole at the other phase of the coil. The polarity may be determined by grasping the coil in the right hand with the fingers pointing in the direction of current flow. The thumb will then be pointing to the north pole. When a soft iron bar is placed in a coil, the lines of force will be concentrated in the iron bar.

ELECTROMAGNETIC INDUCTION

It is known that an electromotive force (emf) can be set up in a circuit or conductor by moving a wire so that it cuts across the lines of force of a magnetic field. The principle is important to us because the entire operation of a generator is based on this theory.

In a simple rotating armature-type generator, the conductors are mounted in the armature and the armature is rotated through the magnetic field which is established by stationary pole-shoes. Voltage is created when these conductors pass or cut through the magnetic field and current will flow when an external circuit is completed.

In the foregoing example, we have induced emf by moving a conductor through a stationary flux or magnetic field of force. There are other ways of inducing emf, such as a moving flux with a stationary conductor. Mutual induction is another form of electromagnetic induction wherein an emf is induced in a conductor by the action of a variable magnetic field originating from a parallel conductor such as is the case in the familiar engine ignition coil.

T I Series No. EL-6

TECHNICAL INFORMATION

KOHLER
ELECTRIC PLANTS
World-Wide

ELECTRICAL

VOLTAGE REGULATION

KOHLER CO. - KOHLER, WIS.

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VOLTAGE REGULATION

The purpose of voltage regulation is to maintain the output voltage of an electric generating plant within certain established limits. The voltage produced at the terminals of a generator depends upon three things. These are:

a. The length of the armature windings.
b. The speed at which the conductor cuts across the magnetic field.
c. The strength of the magnetic field.

In any given machine, a and b are fixed quantities since their values depend upon the physical properties of the generator. To change the length of the windings would require that the machine be taken apart. Obviously, this cannot be done while the machine is moving.

A change of speed at which the conductor cuts across the magnetic field would result in a change in the frequency of the power generated so that this factor must remain unchanged.

The strength of the magnetic field, however, can be varied and in this way, terminal voltage can be adjusted to an appreciable degree.

Direct current is used to excite the field of a generator. Most Kohler electric plants up to 15 KW are of the rotating armature type. On this type of machine excitation is provided by a DC winding in the generator's armature. All Kohler plants above 15 KW are of the revolving field type. On this type, the DC exciter is a small separate generator. Regardless of whether the type is rotating armature or revolving field, line voltage is controlled by varying the strength of the magnetic field.

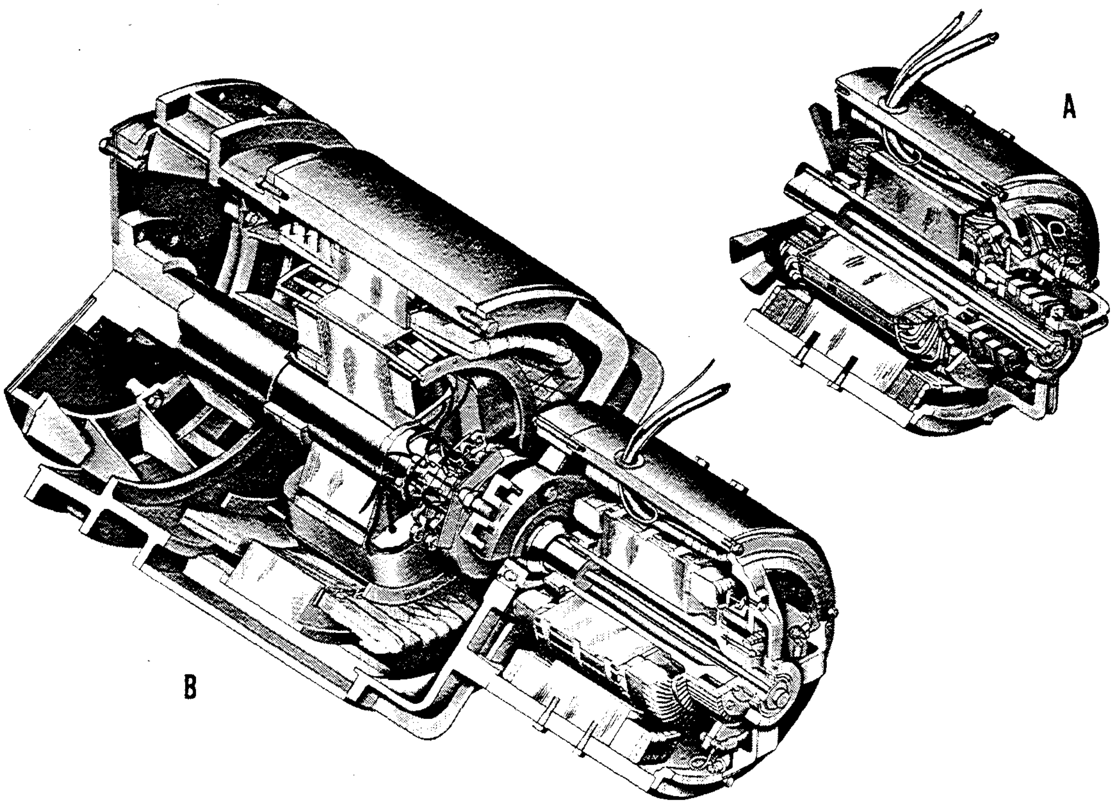

FIGURE 1 - BASIC GENERATOR TYPES

A-Rotating Armature B-Revolving Field

If a generator is run up to its rated speed, excitation can be adjusted to set the terminal voltage at the nameplate value. When electric load is applied, the terminal voltage will drop off, and the more load we apply, the more voltage will drop. This kind of voltage behavior is very undesirable and something has to be done about it. The only thing that can be done is to control the strength of the magnetic field, and this can be accomplished by increasing the excitation. This is done manually or automatically. Most Kohler battery charging units use a rheostat to manually regulate voltage.

As stated above, an increase in load tends to make a generator's voltage fall. As an explanation of this let's take, for example, a typical shunt wound generator and trace its operation.

Since the field coils in a shunt generator are wound with a large number of turns of fine insulated wire, the resistance of the field circuit is high compared to that of the external circuit. The current divides between these circuits with the majority of current flowing in the path of least resistance or the external circuit. Because the resistance of the shunt field circuit remains constant, the current flowing through the field coils will be directly proportional to the voltage induced in the armature.

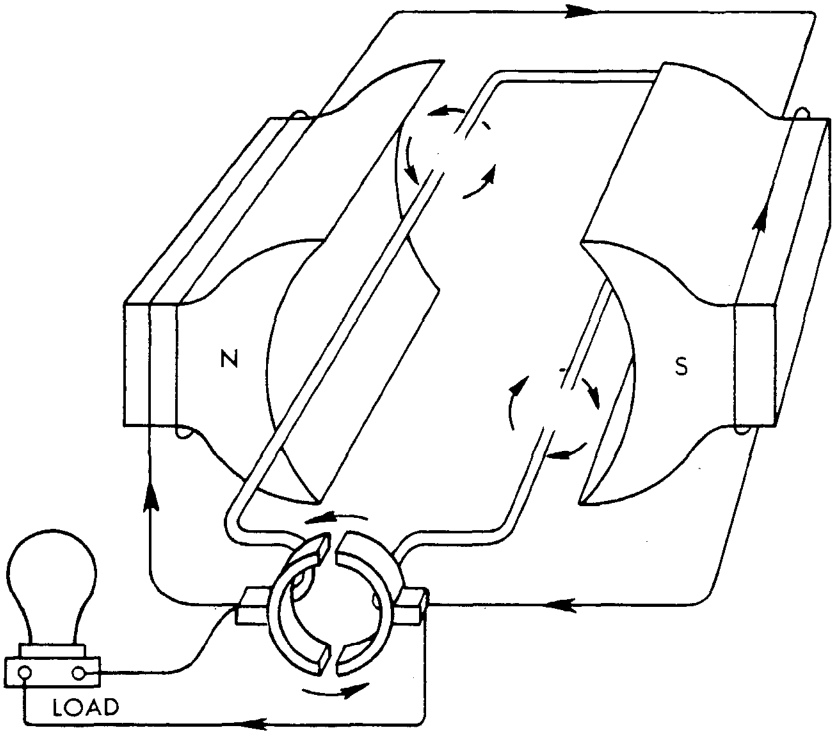

FIGURE 2 - SHUNT WOUND GENERATOR
Load connected in parallel
with field windings.

As the armature starts to revolve, the armature windings cut the lines of force in the residual magnetic field between the pole pieces and generate a small residual voltage in the armature circuit. This causes a small current to flow through the shunt field windings intensifying the field magnetism. As the field magnetism increases and the armature windings cut more lines of force at increasing speed, the induced voltage at the armature increases. This voltage build-up occurs rapidly at first, but after the field poles become saturated magnetically, further increases in voltage are in direct proportion to the armature speed.

↑ ↓

As load is increased, the external circuit resistance is decreased. As we saw in the foregoing, the current seeks a path of least resistance and therefore additional current will be routed through the external circuit. The shunt field current remains directly proportional to the line voltage. As load is added, current increases in the external circuit and armature.

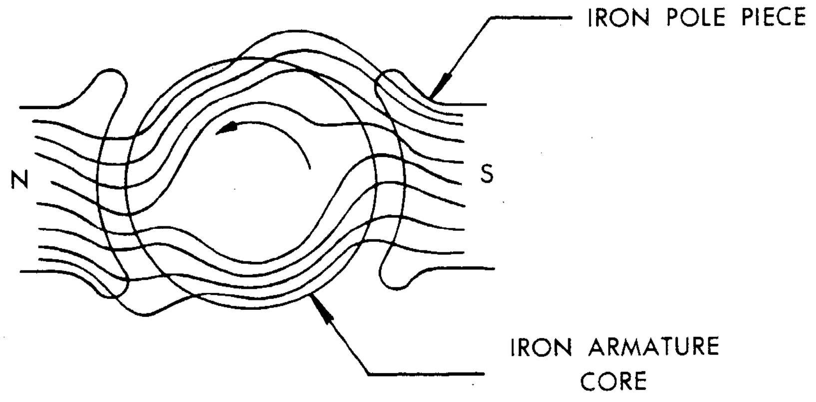

FIGURE 3 - MAGNETIC FLUX DISTORTION

The increased current in the armature distorts the magnetic flux of the field resulting in a drop in voltage output in the external circuit.

VOLTAGE REGULATION METHODS

Kohler electric plants are provided with voltage regulation ranging from 10 percent on the smallest units down to plus or minus 2 percent on the larger plants. Five different methods of obtaining voltage regulation are used. The accompanying table describes the types used on the various plants.

KOHLER ELECTRIC PLANTS - VOLTAGE REGULATION

SIZE ELECT PLANT (KW)	SATURATED POLE SYSTEM	ONE STEP FIELD RELAY SYSTEM	VOLTAGE STABILIZER SYSTEM	VOLTAGE REGULATOR (TYPE*)	
				ELECTRO-MECHANICAL*	STATIC TYPE**
0.5	X				
0.75	X				
1.0		X			
1.25		X			
1.5	X				
2.0	X				
2.5	X				
3.0	X				
3.5			X		
4.0	X				
5.0			X		
6.5			X		
7.5			X		
10.0			X		X
12.5			X		X
15.0			X		X
25. - 30.				X	X
40. - 45.				X	X
50. - 55.				X	X
60. - 75.				X	X
75. - 85.				X	X
100. - 110.					X
150. - 175.				X	X
200. - 225.					X

Through good regulation, voltage can be held within rated limits under conditions of changing load demand. No method of voltage regulation, no matter how refined, will completely eliminate voltage fluctuation. A certain amount of fluctuation is normal due to inherant characteristics of electricity. Voltage regulation is provided to minimize fluctuation and quickly restore normal voltage. The methods used on Kohler electric plants are as follows:

Manual Regulation

Most Kohler battery charging plants have a rheostat in the shunt field circuit to manually adjust the charging rate by varying the shunt field current. Voltage is adjusted by changing the current in the shunt field by means of the rheostat. Adding resistance in the shunt field circuit with a rheostat decreases the generator voltage because less current flows in the field. Therefore, the battery charging rate is lowered. Starting from the plus or positive generator brush, as seen in Figure 4, current flows through the coil of the shunt field through the rheostat and to the minus or negative brush.

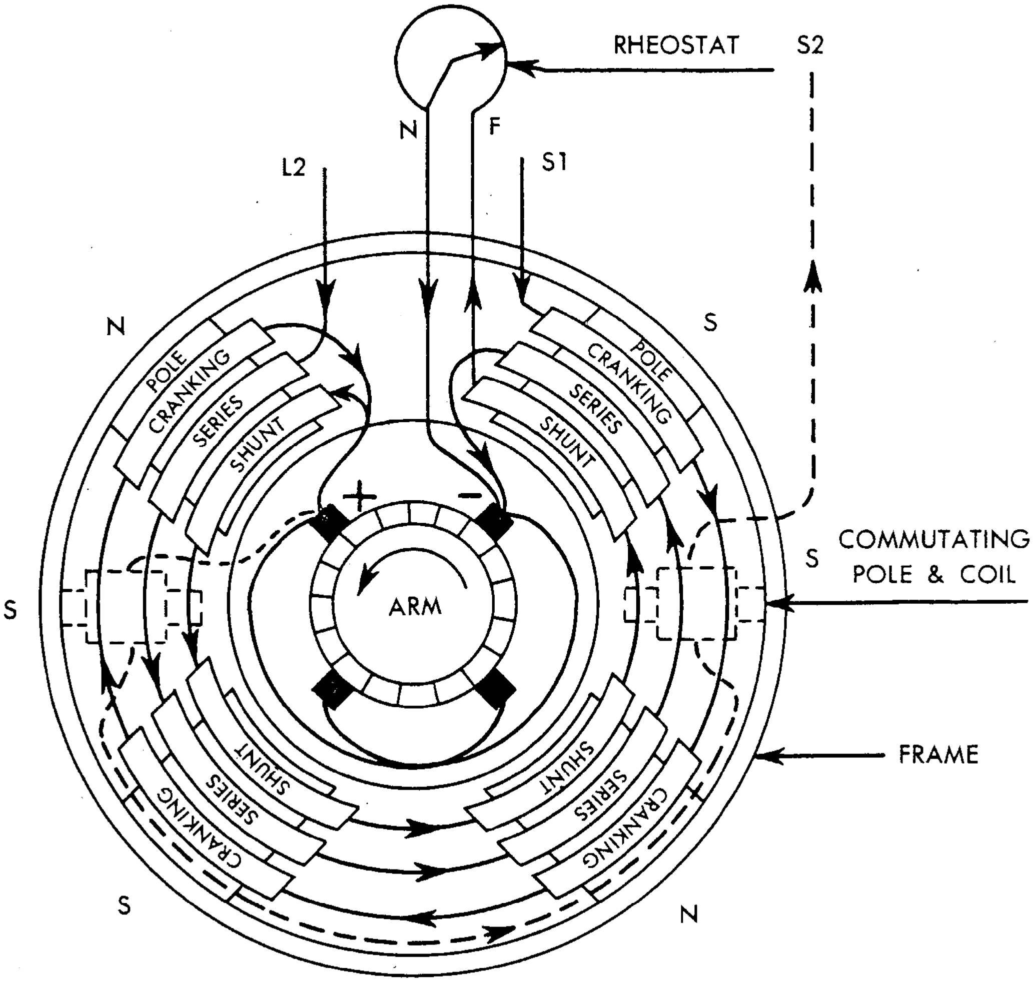

FIGURE 4 - MANUALLY CONTROLLER (RHEOSTAT) BATTERY CHARGING GENERATOR

Saturated Pole

The simplest non-manual method of obtaining good voltage regulation is found in the design of the saturated pole generator. The inherant regulation characteristics of a generator can be improved by designing the winding so that a very strong field is achieved. Thus, the demagnetizing effects of load current are minimized. With this type of regulation, voltage always goes down with load. Saturated pole generators have a voltage regulation of about 10 percent at unity power factor.

One-Step Field Relay

The Kohler 1.25 KW generator uses a relay (S) with a contact in the field circuit which closes at about half load. This relay shorts out a resistor in the field circuit and thus increases the field current sufficiently to return the output voltage to approximately no load value. This generator has an over-all regulation of about 5 percent.

Voltage Stabilizer

The voltage stabilizer type machine is used on 3.5 to 15 KW generators. This machine has auxiliary field windings. A current transformer is inserted in the line to change AC load current to a lower value and then rectify it to DC. This DC current is then passed into the auxiliary field. Current in this field then varies directly with line current. This is not a true voltage regulator because it senses current rather than voltage. There is a real advantage, however, in responding to line current as it makes a response practically instantaneous. When a motor is started, the voltage has no opportunity to drop as the increased field current is applied immediately. Regulation obtained by this means is about plus or minus 5 percent depending upon power factor.

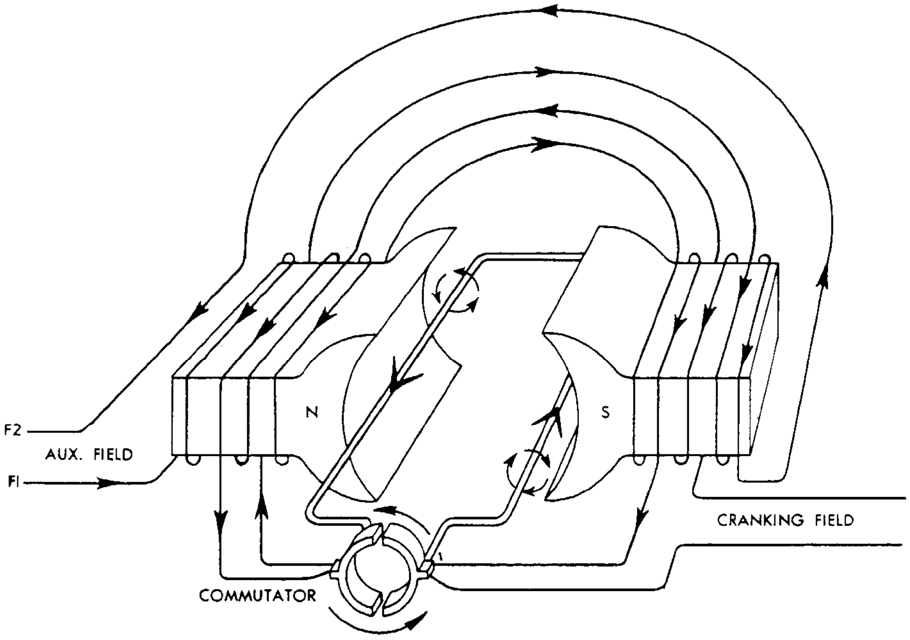

FIGURE 5 - AUXILIARY FIELD WINDINGS

Voltage Regulators

A true voltage regulator is a device that continuously senses the terminal voltage of a generator and adjusts excitation so that voltage remains essentially constant as load varies within the capacity of the generator. There are many different types of regulators and may vary in reacting speed and accuracy of control. Some are intended to regulate plus or minus 2 to 5 percent while others are designed to regulate within a close tolerance of approximately 1 percent. The voltage regulators used on certain of the larger

Kohler electric plant models can be classified under two general types -- the electromechanical and the static type regulators. Utilization of the static type regulator is increasing as they are generally faster reacting and are capable of closer regulation.

Electromechanical Type

The electromechanical regulators are perhaps the simplest voltage regulator types and are used on revolving field generators with the conventional rotating DC exciter. This regulator has a relay type coil which senses AC voltage. The desired control of field current is obtained by a set of multiple finger contacts which add or remove resistors from the exciter field circuit. The exciter field voltage is obtained from the exciter armature for this type of regulation. The response obtained by this method is not as fast as from the voltage stabilizer type but over-all regulation is better, at about plus or minus 2 percent. The electromechanical regulator is not effected by speed droop or power factor to any great extent.

Static Type

The static voltage regulator also senses AC voltage. It is called static since it has no moving parts. The static type voltage regulator now in use on Kohler electric plants consists of a transformer, transistors, diodes, capacitors and resistors. This type of regulator acts as an automatic field rheostat which precisely controls the field current in order to maintain a constant voltage output of the generator. AC current flowing through the resistors also causes current to flow in the transistors which form a sensing circuit. The AC voltage in the sensing circuit is stepped down, rectified, and filtered to form a DC sensing signal. A fraction of the signal is compared to the voltage across a reference diode to develop an error signal. For example, when the voltage across becomes too high, the sensing circuit produces a positive error signal which is applied to the base of one of the transistors. This causes an increase in the collector current of a certain transistor and a corresponding decrease in the current through all the other transistors. The response obtained by static regulators is fast and is not effected by speed droop or power factor to any great extent. Since there are no mechanically operated parts, these regulators, which employ magnetic and electronic circuits, generally react much faster than other types. Voltage regulation obtained by static regulators can be plus or minus 2 percent and even closer in many instances.

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T I Series No. EL-7

TECHNICAL INFORMATION

KOHLER
ELECTRIC PLANTS
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ELECTRICAL

MOTOR STARTING

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ELECTRICAL

MOTOR STARTING

EFFECTS OF MOTOR STARTING

No single factor affects line voltage as much as the starting of AC motors. The usual AC motor draws a tremendous amount of current at the instant power is connected. The starting or so called in-rush current demanded by a motor can be as high as 6 to 10 times that demanded when it is up to normal running speed.

High Current Draw

A motor with its rotor held so that it cannot rotate, draws approximately the same amount of current as a motor would upon starting. This is referred to as the locked-rotor starting KVA of a motor. The NEMA table which determines the locked-rotor or starting KVA of different sizes of motors is given in the following section under Load Analysis. Until a motor attains approximately 2/3 of its normal speed, the current that it demands remains at or near this locked-rotor value.

Low Power Factor

Along with high starting current demand, there is also a corresponding decrease in power factor. The lower the speed, the lower the power factor in the commonly encountered AC induction motors. Also at no-load, the power factor of this type of motor is very low.

Voltage Dip

Sudden application of this heavy current demand at starting, coupled with a very low power factor, results in a voltage dip.

As voltage drops, the situation is eased somewhat because the current drawn by the motor will drop as the voltage drops. Apparently, the situation would take care of itself automatically, that is, the motor would gradually come up to speed and as it did so, the generator would also come up to voltage. This does happen, but only within certain limits, since there is a limit to how much voltage drop can be tolerated.

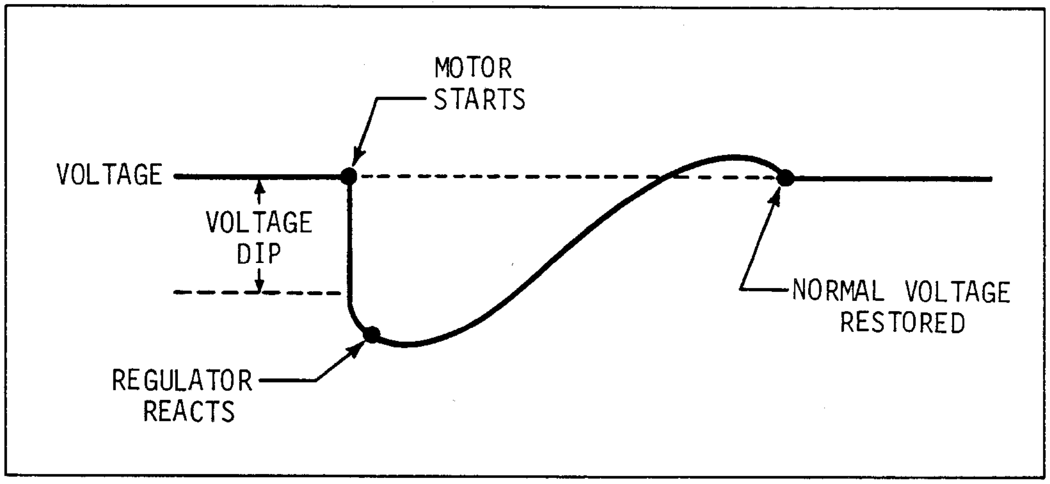

FIGURE 1 - MOTOR STARTING EFFECTS ON LINE VOLTAGE .

Full Voltage or "Across The Line" Starting

Motor starters are frequently used with motors. These devices usually consist of magnetic contactors which will automatically drop the motor off the line when voltage drops to a certain level. When the motor drops off the line, the generator will be momentarily relieved and its voltage will then rise. As the voltage rises, the control device will automatically reconnect the motor across the line.

If the generator size is marginal, there is a danger that the contactor will keep opening and closing indefinitely until it pounds itself to pieces. Generally, a contactor will remain closed down to around 50-60 percent of the motor's voltage rating, so the capacity of the generator should be large enough to insure that voltage stays above this drop-out point.

Motor Load - Starting Torque

Another factor to be considered is the application of the motor itself. If the motor drives a piece of equipment which is engaged only when the motor reaches normal speed, then load starting torque need not be considered. In other instances, the motor will have to start equipment requiring high starting torque.

Sufficient voltage must be available to insure that a motor can develop enough torque to start its load. As voltage decreases, the available torque drops to an even lower degree. Mathematically speaking, torque varies inversely as a square of voltage. As an example of this, if the voltage supplied to the motor drops to 70 percent of its normal value, the available torque drops off to only 49 percent of what it would be if voltage was held at the normal level. In some cases, it may be that at this low torque value, the motor could not start let alone get up to its normal running speed.

Reduced Voltage Starters

Up to this point, the discussion has been on full voltage starting. Reduced voltage starting methods are employed whenever the starting torque of driven equipment has to be applied gradually or in applications where the starting current produces objectionable line disturbances. Where reduced voltage starters are involved, it is possible to start motors about half again as large as could be started at full voltage or across the line from the same generator. However, it is important to note that when the voltage is reduced in starting a motor, the current is also reduced and so is the torque which the machine can deliver.

If the motor is driving a fan or blower or other similar equipment where little if any starting torque is required, load on the motor builds up very slowly at first and is not of any appreciable amount until the motor is up to about 3/4 speed. This sort of application makes good use of a reduced voltage starter. Other drives where reduced voltage starters can be used to advantage are applications where the motor is started and brought up to speed before the load is applied.

AC MOTORS

To more fully understand the problems involved in motor starting, it is imperative that we review some of the more common types of AC motors. According to NEMA standards, motors are classified according to application and electrical types. There are also other classifications but these do not add to our study.

Motor Classification According to Application

The following is a partial listing of motor definitions according to application. These are definitions of the type more commonly encountered.

General Purpose Motors. A general purpose motor is an open motor having a continuous 40° C. rating and designed, listed and offered in standard ratings with standard operating characteristics and mechanical construction for use under usual service conditions without restriction to a particular application or type of application.

Special Purpose Motors. A special purpose motor is a motor with special operating characteristics or special mechanical construction, or both, and is designed for a particular application.

Part Winding Start Motors. A part winding start induction or synchronous motor is one arranged for starting by first energizing part of its primary winding and subsequently energizing the remainder of this winding in one or more steps. The purpose is to reduce the initial values of the starting current drawn or the starting torque developed by the motor. A standard part winding start induction motor is arranged so that one-half of its primary winding can be energized initially and, subsequently, the remaining half can be energized. Both halves then carry the same current.

Motor Classification According to Electrical Type

Alternating current motors are of three general types which are induction, synchronous and series wound.

Induction motors are the type most commonly encountered in the field. In this type a primary winding in one member, usually the stator, is connected to the power source and a polyphase secondary winding, usually the rotor, carries induced current. Current induced in the rotor causes it to revolve. Induction motors, as the name implies, cause inductive reactance and, therefore, operate at lagging power factor which, at starting, is very low. Starting power factor ranges from 0.3 to 0.5 depending upon the class of motor. Also, at no-load, the power factor of induction motors is very low while at part and full-load the power factor tends to be much higher.

When started across the line, the current drawn by an induction motor can be from 350 to 750 percent of full-load current. This coupled with low power factor can cause excessive line disturbances.

Alternating current motors are manufactured in either single phase or poly-phase versions. There are many different types with widely varied starting characteristics. The most common types fall under the following phase classifications.

Single Phase Types

1. Capacitor (Induction)
2. Split-phase (Induction)
3. Repulsion induction

Poly-phase Types

1. Squirrel cage induction
2. Wound rotor induction
3. Synchronous

SINGLE PHASE TYPES

Capacitor Motors

Capacitor motors have an extra starter winding in the stator which receives current that must pass through a capacitor. The capacitor causes the current in the auxiliary winding and the current in the main winding to be nearly out of phase by 90 electric degrees. This sets up a rotating magnetic field which the rotor tends to follow. The starter winding is opened by a centrifugal switch at about 70 percent of the final speed. The capacitor motors chief advantage is its unusually high starting torque without excessive starting current. Capacitor motors are usually found in 1/8 to 1 HP sizes, but they are occasionally found in sizes ranging up to 10 HP.

Split Phase

The split phase motor also uses an auxiliary starter winding in the stator. The starter winding is wound with a smaller wire size than that of the running winding and since the smaller wire has more resistance, the current in the starter winding reaches a peak flow between the peaks of the running winding. Thus a rotating field is produced which starts the motor. A centrifugal switch opens at approximately 70 percent of running speed to disconnect the starter winding. The split phase motor, although found in many applications, is perhaps the poorest in starting characteristics because of the extremely high starting current draw.

Repulsion Induction

Unlike the split phase and capacitor motors, the repulsion induction motor has an auxiliary starter winding on the rotor rather than in the stator. Its rotor is of more complicated design with a DC armature winding, commutator and a centrifugal mechanism for disconnecting the commutator.

Current in the stator winding induces current in the rotor starter winding which in turn produces a magnetic field. The magnetic field of the stator windings repels the magnetic field produced by the rotor windings and causes the rotor to revolve. A brush mechanism rides on the commutator until the motor reaches its rated speed, when the linkage connected to the flywheel disconnects these brushes. The DC rotor is converted into what is in effect a squirrel cage induction rotor at this point. At full speed then the motor runs as though it were a squirrel cage induction motor.

The starting characteristics of repulsion induction motors are quite good since they possess high starting torque and low starting current. Usual ratings of the repulsion induction motors are from 1/8 to 10 HP.

POLY-PHASE TYPE MOTORS

Poly-phase induction motors are usually three phase with their windings placed 120 degrees apart. The rotating field set up by the stator causes the rotor to turn at a speed slightly less than synchronous speed.

In a poly-phase motor the problem of attaining rotation is not a factor since in three phase current the flow reaches a peak more than once in each cycle. This poly-phase current allows current to reach a peak in one coil, then the second, the third and so on which produces a rotating magnetic field. This causes the squirrel cage rotor of either the induction or synchronous motor to rotate.

Squirrel Cage Induction Motors

This type of motor derives its name from its design resemblance to the typical squirrel cage. Squirrel cage induction motors can be broken down into four general starting torque classifications which are:

1. Normal Torque - Normal Starting Current. This type is used in about 90 percent of the induction motor applications. They are used where excessive starting torque is not required such as fans, blowers, pumps and unloaded compressors.

2. Normal Torque - Low Starting Current. This type is used where the starting current must be lower than that needed by a normal starting current motor.

3. High Starting Torque - Low Starting Current. This type is used where high starting torque is required, for example, on plunger pumps, loaded compressors and loaded conveyors.

4. High Starting Torque - High Slip Type. These are used for flywheel loads.

Wound Rotor Induction Motors

Wound rotor or so called slip ring induction motors have windings of coils placed in the rotor rather than bars as is the case in squirrel cage induction motors. This type of motor is used on heavy starting applications where control of acceleration is necessary.

Synchronous Motors

Synchronous motors rely on direct current from a small exciter for excitation. Direct current is fed to the rotor field through brushes and slip rings. The combination of AC and DC power used in these motors gives them the characteristic of running at a constant speed. Synchronous motors, therefore, provide a constant speed plus the excellent advantage of adjustable leading power factor. They also have good starting torque and overload capacity. Adjusting the power factor is accomplished by changing the DC excitation supplied to the rotating poles. Generally synchronous motors are found in two separate classes, high speed and low speed.

In the following table we give some of the characteristics on the motors just discussed. Whatever the type, all the nameplate data regarding horsepower, line voltage, amps and starting control should be analyzed before the correct size electric plant can be recommended.

SINGLE PHASE TYPE	STARTING TORQUE	STARTING CURRENT	USES & COMMENTS
Capacitor	High	Medium	Farm Elevators - Pumps Up to 5 H.P.
Split Phase	Low	Very High	Easy Starting Applications Furnace Fans
Repulsion Induction	High	Low	Refrigeration - Fans Logging Saws Used 3 H.P. & above
POLYPHASE TYPE			
Squirrel Cage Induction	Low to Normal	High	Very efficient, many applications
Wound Rotor Induction	High	High Use with Starting Control	Air Compressors, Printing Presses Machinery Starting Under Load
Synchronous	Low to High	Low to High Depending on Size	Reciprocating Compressors, Chippers Grinders High Efficiency

TABLE 1 - AC MOTORS AND CHARACTERISTICS

LOAD ANALYSIS OF MOTOR STARTING

Selection of the right electric plant for applications involving motor starting is made more difficult by the numerous types of motors and their different starting characteristics. The most important thing is that a thorough and accurate analysis is made in each particular case. The following factors must be taken into consideration for an accurate analysis.

1. Determine the amount of load (if any) that will be on the line when the motor is started.
2. Determine motor starting KVA. The standard horsepower rating and starting or locked rotor KVA NEMA code letter is given on the nameplate of most motors. Where this is not given, the motor manufacturer should be consulted for starting data on the particular motor involved. The accompanying NEMA Standard Starting KVA Table can be used to determine the generator size required to start a particular general purpose motor. The table lists the code letters and the multiplication factor applicable to the code letter.

CODE LETTER	STARTING KVA PER H.P. *
A	0 - 3.15
B	3.15 - 3.55
C	3.55 - 4.0
D	4.0 - 4.5
E	4.5 - 5.0
F	5.0 - 5.6
G	5.6 - 6.3
H	6.3 - 7.1
J	7.1 - 8.0
K	8.0 - 9.0
L	9.0 - 10.0
M	10.0 - 11.2
N	11.2 - 12.5
P	12.5 - 14.0
R	14.0 - 16.0
S	16.0 - 18.0
T	18.0 - 20.0
U	20.0 - 22.4
V	22.4 - and up

* Starting KVA per horsepower range includes the lower figure up to, but not including, the higher figure. Example: 3.14 is designated by letter A, 3.15 by letter B

TABLE 2 - STARTING KVA OF MOTORS (NEMA STANDARD)

Referring to the starting KVA table, a code "F" motor, for example, requires 5 to 5.59 starting KVA per horsepower. Thus a 15 horsepower NEMA code "F" requires between 75 and 84 KVA to start at full voltage. Kohler generators are capable of supplying approximately 2 starting KVA per rated continuous KVA. A 40KW-50KVA plant could be expected to start this motor satisfactorily.

3. Starting Control. Usually the limiting factor in motor starting is the voltage at which the starting contactor will drop out. We must stay above this voltage. Drop out voltages for standard AC contactor is in the range of half their rating. Thus the electric plant must maintain 60 to 70 percent voltage during the starting period. Specifications often require 75 percent voltage. This requirement will often make a size larger plant necessary than would be required if lower voltage could be tolerated. The accompanying curves show the voltage dip anticipated when starting induction motors.

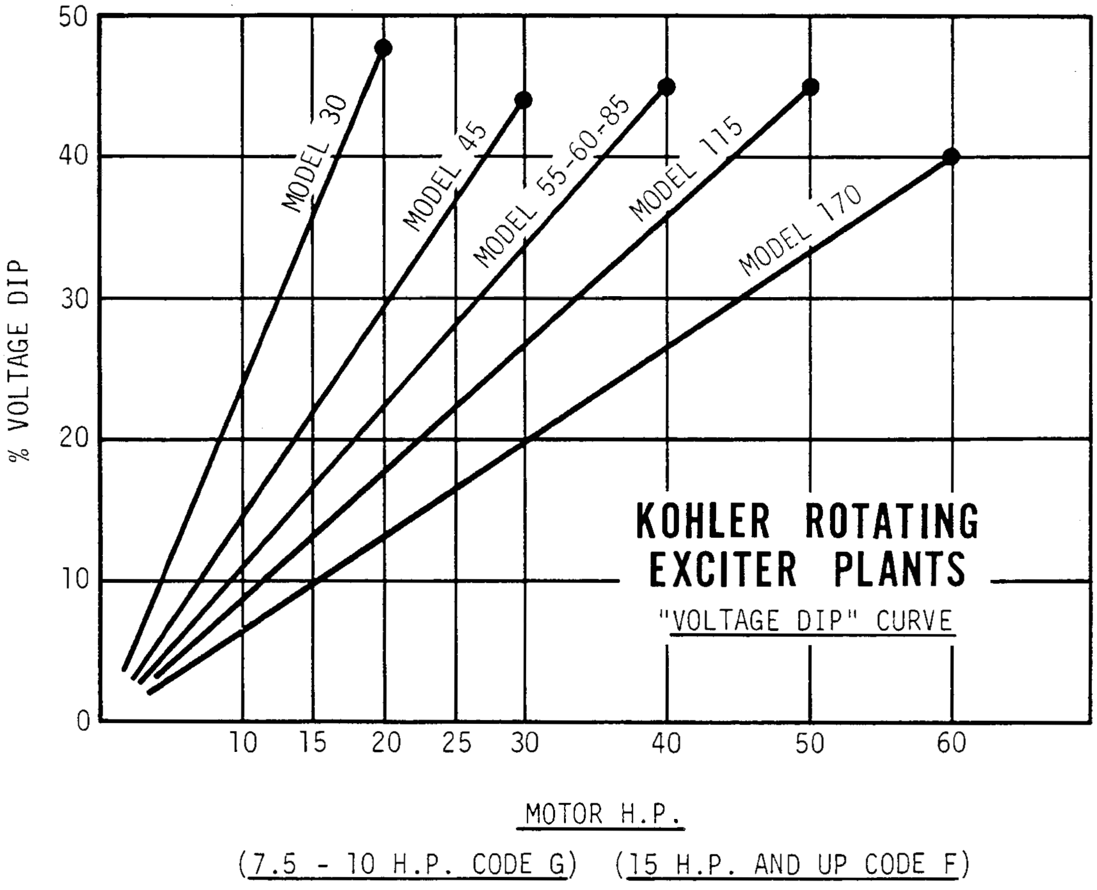

FIGURE 2 -- VOLTAGE DIP CURVE FOR REVOLVING EXCITER PLANTS

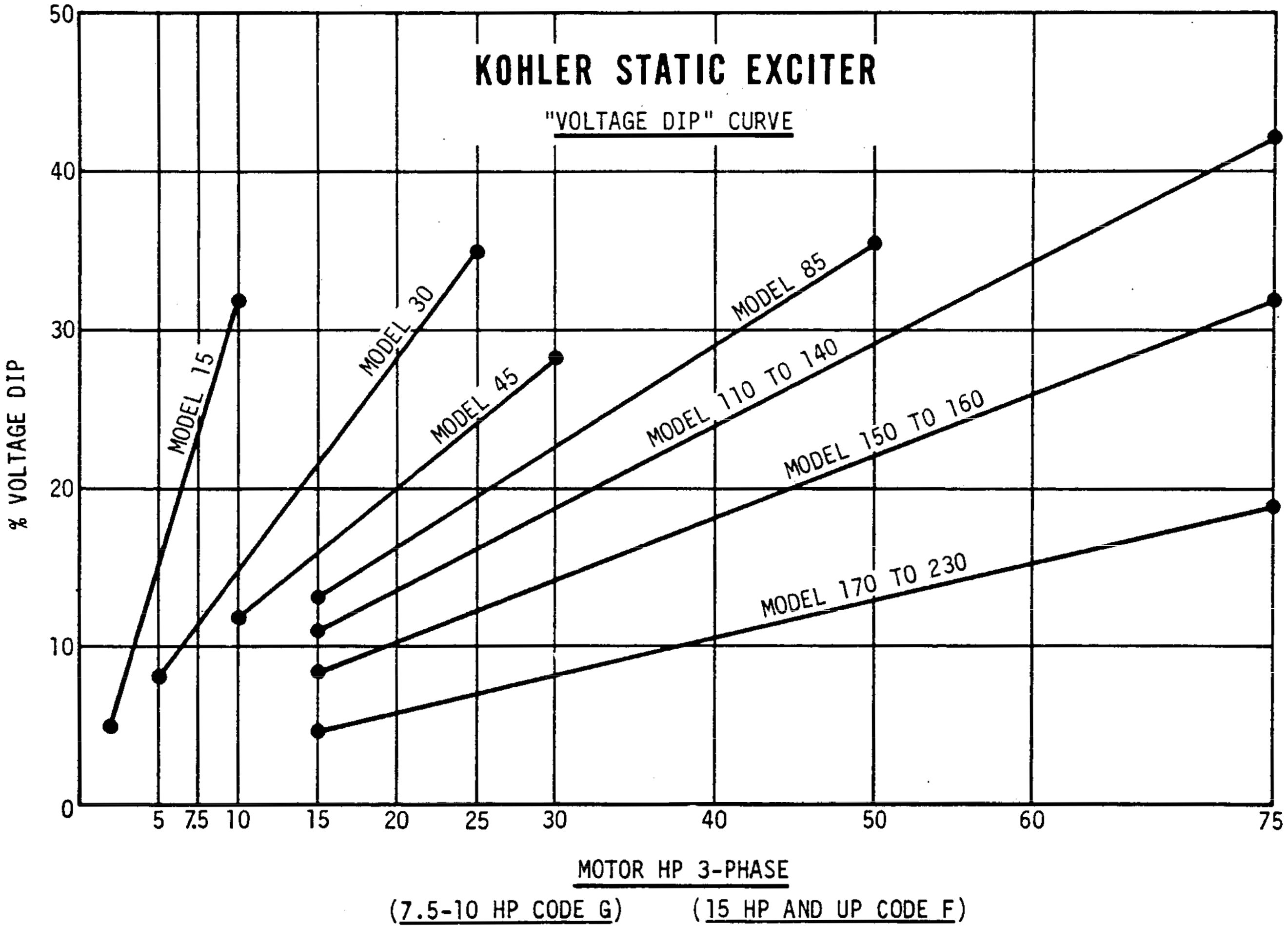

FIGURE 3 -- VOLTAGE DIP CURVE FOR STATIC EXCITER PLANTS

Where it can be used, part voltage starting is very helpful in preventing too much voltage drop during motor starting. Very little of this will be found below 50 horsepower. It is common above 50 horsepower because many power companies will not permit larger motors to be started across the line on their systems.

4. Motor Load. An equally important factor in motor starting is the type of load which the motor is required to accelerate. Hard starting loads such as piston type pumps require at least one size larger plant than indicated in the following Kohler motor starting tabulation.

Starting more than one motor on a plant involves the following. If delayed starting of the second motor is used, the second motor may be one size smaller than the recommended size for the first one. Thus a 5KW plant could be used to start a 2 and 3 horsepower motor providing the starting of the 2 horsepower motor is delayed until after the three horsepower motor is up to running speed. If it is necessary to start both motors at once, the total horsepower should be somewhat less than that recommended for one motor.

Electric Plant Recommendations. Since there are so many variables involved in motor starting, the following table listing the various size plants required for starting some typical motors should be used with caution. It should be used only as a guide for typical situations and it is not intended as a substitute for thorough analysis of any application.

MOTOR STARTING

The following maximum motor horsepower ratings will be helpful in recommending a proper size plant.

Size Plant	Max. Motor Horsepower
750 watt	Small shaded pole or series
1.25 KW	1/4 H.P. capacitor
	1/8 H.P. split-phase
1.5 KW	1/3 H.P. repulsion-induction
	1/4 H.P. capacitor
	1/4 H.P. split-phase
2.5 KW	1/2 H.P. capacitor
	3/4 H.P. repulsion-induction
4 KW	2 H.P. repulsion-induction
5 KW (single phase)	3 H.P. repulsion-induction
6.5 - 7.5 KW (three phase)	3 H.P. induction
10 KW (single phase)	5 H.P. repulsion-induction
10 KW (three phase)	5 H.P. induction
15 KW (single phase)	7-1/2 H.P. repulsion-induction
15 KW (three phase)	7-1/2 H.P. induction
30 KW (three phase)	10 H.P. induction
45 KW (three phase)	15 H.P. induction
55 KW (three phase)	25 H.P. induction
85 KW (three phase)	30 H.P. induction
115 KW (three phase)	40 H.P. induction
170 KW (three phase)	60 H.P. induction

These recommendations are on the basis of across the line starting of general purpose motors used with 50 percent voltage drop out contactors.

TABLE 3 - KOHLER ELECTRIC PLANT - MOTOR STARTING RECOMMENDATIONS

Load Distribution of Motors

Single Phase - Three Wire - 120/240 V. The single phase three wire system is probably the most practical where a few motors of five horsepower or less are used. Motors one-half horsepower and larger should be rated 240 volts. Loads must be balanced as nearly as possible between legs. If this is not done, it is possible to overload a generator even though it has ample capacity to carry the load if properly balanced. Power factor of the total load must be near unity as our single phase generators are not rated a .8 power factor.

Three Phase - Three Wire. Three phase, three wire systems usually are used where the load is almost entirely motors. Voltages available are 240, 480 and 600. The problem of load analysis is usually one of motor analysis only. All of our three phase plants are rated at .8 power factor lagging.

Three Phase - Four Wire - 120/208V. The system often used where the load is a mixture of lights and motors is 120/208 V. three phase, four wire. Most 220 volt general purpose motors are suitable for operation at 208 volts if the line drop is held to reasonable limits (within 10 volts). The greatest difficulty in applying a generator to such a system usually comes in properly splitting the 120 volt lighting loads. This is particularly true if the normal source for the lights is 120/240 volts single phase. In some cases you may not be able to utilize the full generator capacity because of this unbalance.

Three Phase - Four Wire - 120/240 V. The system most difficult to apply properly is the three phase four wire delta. Unbalanced 120 volt loads on this system load only one-sixth of the generator winding. If you already have the generator half loaded with three phase motors you have only one-twelfth generator capacity left for unbalanced 120 volt load. Another way to look at it and one more likely to be accepted, is to limit the current in any line to not more than 110 percent of nameplate rating. The object should be to balance the 120 volt loads as only the unbalanced 120 volt loads can cause serious trouble. The delta connection will give about 10 percent more voltage dip on motor starting than the wye type.

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TECHNICAL INFORMATION

KOHLER

ELECTRIC PLANTS

CONTROLLERS

KOHLER CO.
Kohler, Wis. 53044

ES-912

CONTENTS

CONTROLLERS

A Controller is an assembly of electrical apparatus used to control the starting, running and opping functions of Kohler Electric Plants. All Controllers are designed, engineered, and manufactured at Kohler and are, therefore, designed specifically for the particular generator set on which they are used. Most components of the Controller are enclosed in a ventilated housing which is conveniently mounted on top of the generator frame. Vibro mounts are used to prevent damage to electrical components from vibration that could otherwise be transmitted from the engine or generator.

Controllers are supplied in a wide range of sizes. The selection depends mainly on the size of the generator set, the application and the number of accessory items used. There are four basic types of Controllers available. The basic types are:

MANUAL (M)	**PUSH BUTTON (C)**	**AUTOMATIC (A)**	**REMOTE (R)**

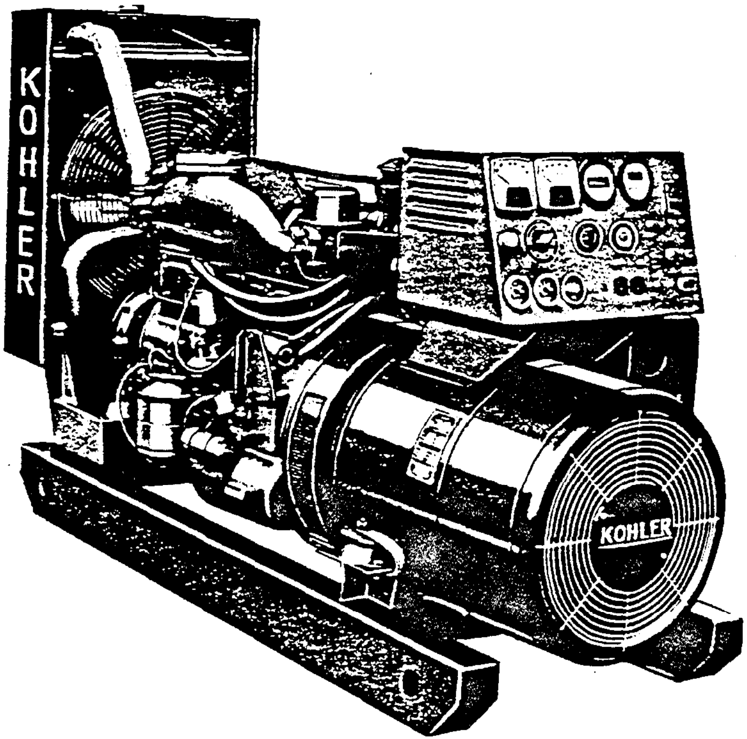


FIGURE 1 -- KOHLER STATIC EXCITER ELECTRIC PLANT WITH SLOPE FRONT CONTROLLER

The first letter designation of the model indicates the type of Controller used, for example: Model 7.5RMK61. The R indicates remote control. The other designations are: A = Automatic, C = Push Button, and M = Manual. A description of the various types follows.

MANUAL (M) CONTROLLERS

With manual controller, the electric plant engine is started manually by rope, retractable starter or hand crank in certain cases. The manual control panel is used primarily on small portable plants. Manual controllers include very few components--usually just AC and/or DC receptacles plus control relay and transformer when the plant is equipped with econo-throttle. Because of the simplicity, this type panel is often referred to as a receptacle box. Electrical plugs are inserted in the receptacles to connect the load. Manual plants are stopped by pressing an ignition ground button or switch on gasoline models or by shutting off fuel on Diesel models.

PUSH BUTTON (C) CONTROLLERS

Push button controllers are used on plants with electric starting. To start, the operator must hold a momentary contact switch in the start position until the engine starts running. The switch is spring loaded to return to the normal open or run position when released. This controller does not disconnect the cranking circuit automatically. The push button controller often has provision for using an additional start-stop switch at a location remote from the electric plant such as inside a motor home or

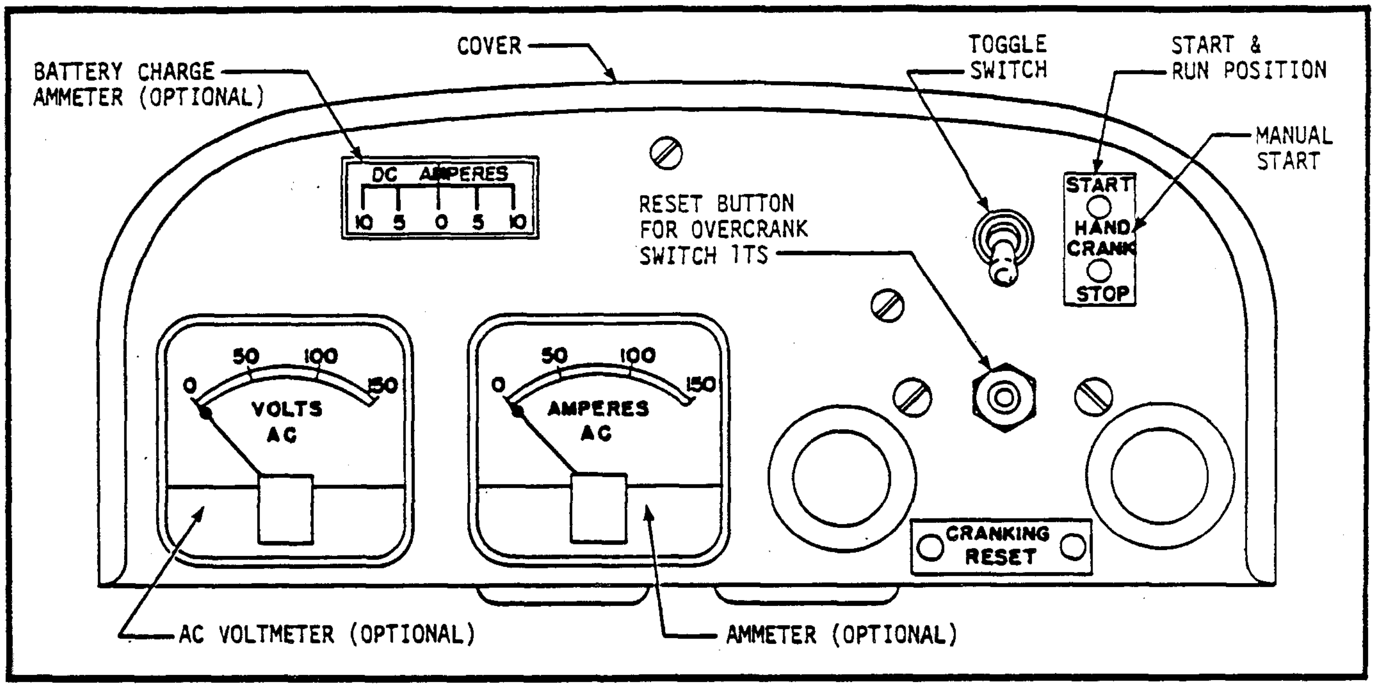


FIGURE 2 -- TYPICAL CONTROLLER PANEL WITH SOME COMMON ACCESSORIES

pilot house of a boat. The push button plant will continue operating until the operator moves the start-stop switch into the stop position--the switch must be held in stop position until the plant comes to a complete halt. The push button controllers include relays, switches, resistors, etc., to monitor the complete operation and protect against possible damage due to malfunction.

AUTOMATIC (A) CONTROLLERS

Automatic controllers allow unattended starting and stopping of an electric start generator set upon load demand. An automatic controller will automatically start the generator set whenever a load of 60 watts (or higher depending on the setting) is imposed on the AC circuit and automatically stop the plant when the load demand is removed. For example, when a refrigerator switches on, it completes an electrical path from the positive side of the starting battery, thru the load circuit and back to the negative side of the battery. Direct current can thus flow thru the completed circuit which energizes a control relay to initiate the start-up procedure. The refrigerator current draw is sensed by a transformer which holds the control relay in the energized position as long as the refrigerator operates--when it switches off, current flow thru the transformer ceases and the control relay de-energizes to stop the plant. Automatic controllers usually include devices to protect against malfunction as this is especially important in unattended operation.

REMOTE (R) CONTROLLERS

The remote controlled plant may be placed in operation by a manually activated start-stop switch located remote from the plant. Remote controller plants may also be used with automatic load transfer panels for unattended operation. With this arrangement, whenever the commercial power fails or drops below a specific voltage level, the transfer panel first signals the controller to start the plant then transfers the load to the plant as soon as it is running. When commercial power is restored, the panel will switch the load from the electric plant back to commercial power allowing the controller to stop the electric plant usually after a brief cooling off period at no load. Remote control plants may be converted to automatic load demand starting by adding a load demand panel.

When the load demand panel is used, the controller is activated to start the generator set only on load demand. For example, in certain applications, it is essential that only certain pieces of equipment, such as an air conditioner or furnace with normal on-off cycles, be kept running during the event of normal power failure. In applications such as these, the load demand panel signals the controller to start the generator set, the controller then runs the generator set only until such time that the load demand panel signals that a load is no longer present on the line. The controller then automatically shuts down the generator set.

COMMON COMPONENTS

In order to understand the operation and function of controllers, it is necessary to be able to identify and understand the principle of operation of the basic components. Because of the variation in controllers, all of the components described may or may not be found in any one given controller.

The following section covers the components common to most controllers. Note that in some cases, two different identifying symbols are shown. This is due to the fact that one symbol is used to identify the component on the locating wiring diagram while the other symbol is used on the line diagram. These diagrams will be explained in detail later.

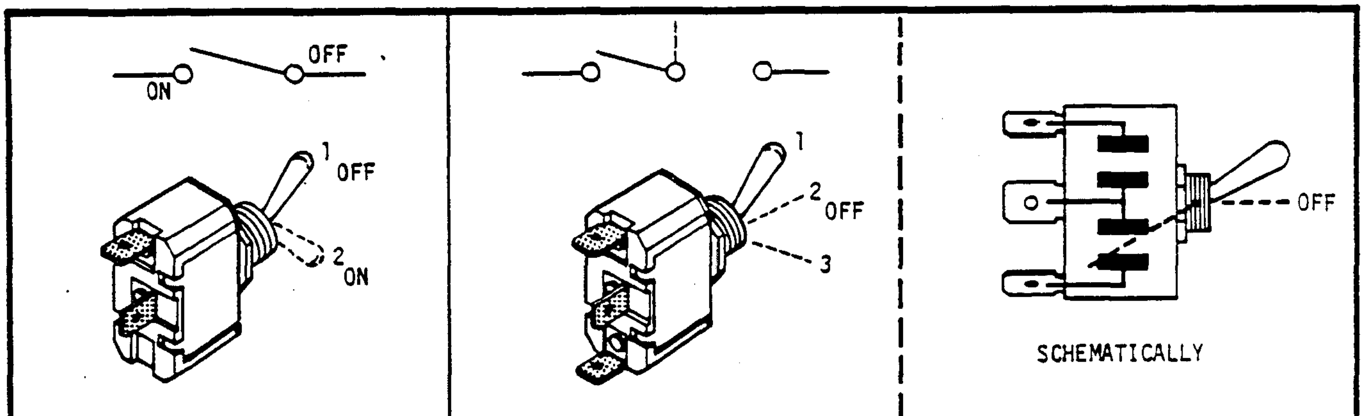
SWITCHES

A switch is a device used to open, close or divert an electrical circuit. They can be activated manually or automatically. Mechanical, electro-magnetic, electro-mechanical and other methods are used to activate switches. Automatic switches are often referred to by a proper name, for example, circuit breaker, thermal relay--even the common fuse can be classified as a switch. These will be discussed later under their individual names. Figure 3 shows some manually activated toggle switches in common use on Kohler Controllers.

PROTECTIVE DEVICES

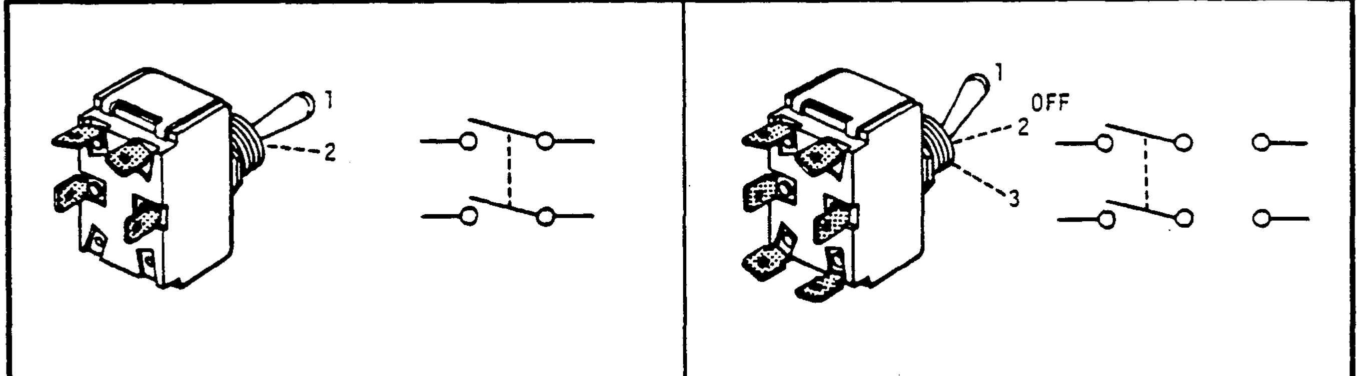
Fuse: A fuse can be thought of as another type of a switch since it functions to open or break a circuit when current flow becomes excessive. The fuse consists of a piece of metal with a low melting point. The fuse is inserted in series with the circuit that it is to protect. When current flowing through the fuse exceeds the maximum safe value, the metal melts, thereby breaking the circuit.

Circuit Breakers: A circuit breaker protects a circuit against short circuits and overloading. One type of circuit breaker consists of an electro-magnet with coil windings that are in series with the load to be protected and with switch contact points. Excessive current causes the magnet to become energized and to trip the switch which breaks the circuit to the circuit breaker and the load. When the circuit fault has been corrected, the circuit breaker must usually be reset manually.



SINGLE POLE - SINGLE THROW

SINGLE POLE - DOUBLE THROW



DOUBLE POLE - SINGLE THROW

DOUBLE POLE - DOUBLE THROW

FIGURE 3 -- COMMON TOGGLE SWITCHES

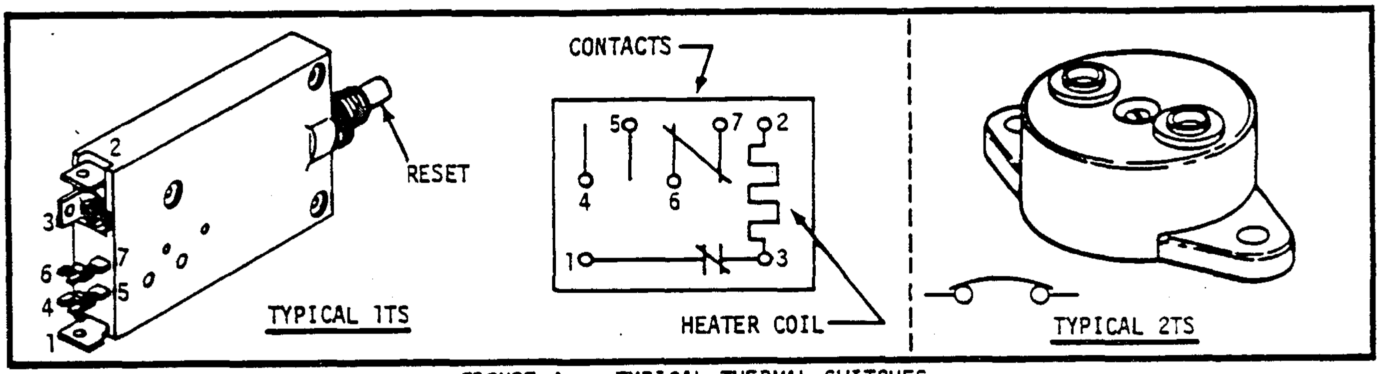


FIGURE 4 -- TYPICAL THERMAL SWITCHES

Thermal Switch or Relay: Thermal relays protect a circuit from overheating and can be used as time delays. One type consists of a fine metal strip in which two metals having different rates of expansion are welded together. When the fine metal is heated, it bends causing a set of contacts to open. Another type of thermal relay consists of a ratchet mechanism and a coil. When the coil overheats, the solder melts, releasing the ratchet which in turn releases the circuit. A thermal relay thus depends upon a thermal or heat element to energize before the switching mechanism can operate. Thermal switches or relays are indicated by TS--the 1TS type must be manually reset while the 2TS type will reset itself after it has cooled sufficiently.

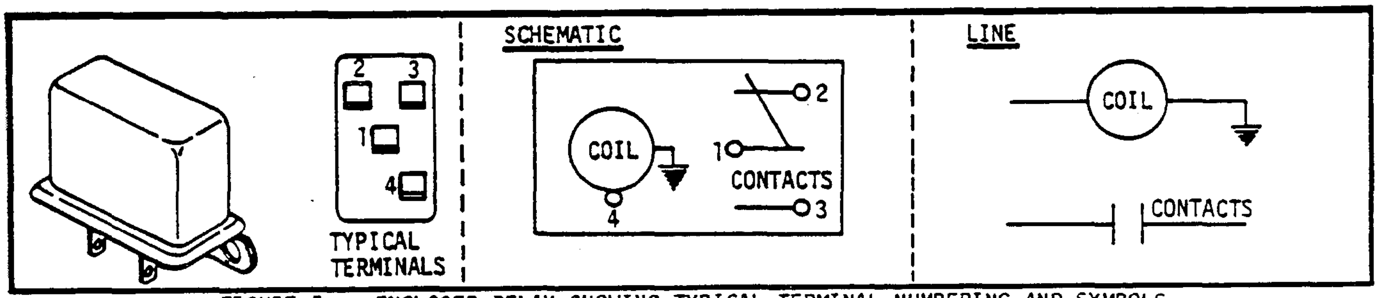
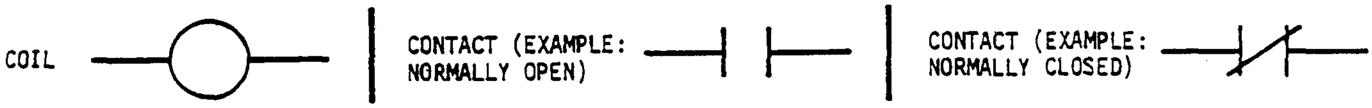


FIGURE 5 -- ENCLOSED RELAY SHOWING TYPICAL TERMINAL NUMBERING AND SYMBOLS

RELAYS

A relay can be thought of as an electrically operated switch that is energized to activate other remote circuits. A typical relay consists of a core, a coil, one or more sets of contact points and a spring held armature. When current flows through the coil, the core becomes an electro-magnet and attracts the armature which either opens or closes the contact points which in turn either make or break other circuits. They are manufactured in normally open or normally closed or with both types. The symbol for the coil and the contact that it activates are shown as follows:



In tracing the operation of a circuit on the line diagram, look for the letter designation within the symbol of the coil, for example: Coil CR will activate contact CR which is shown at some other location on the diagram. One coil may activate several contact points at different locations on the diagram.

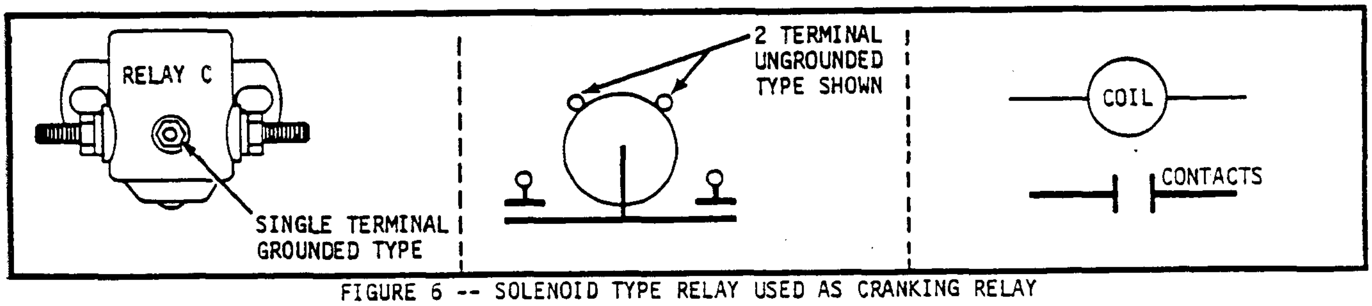


FIGURE 6 -- SOLENOID TYPE RELAY USED AS CRANKING RELAY

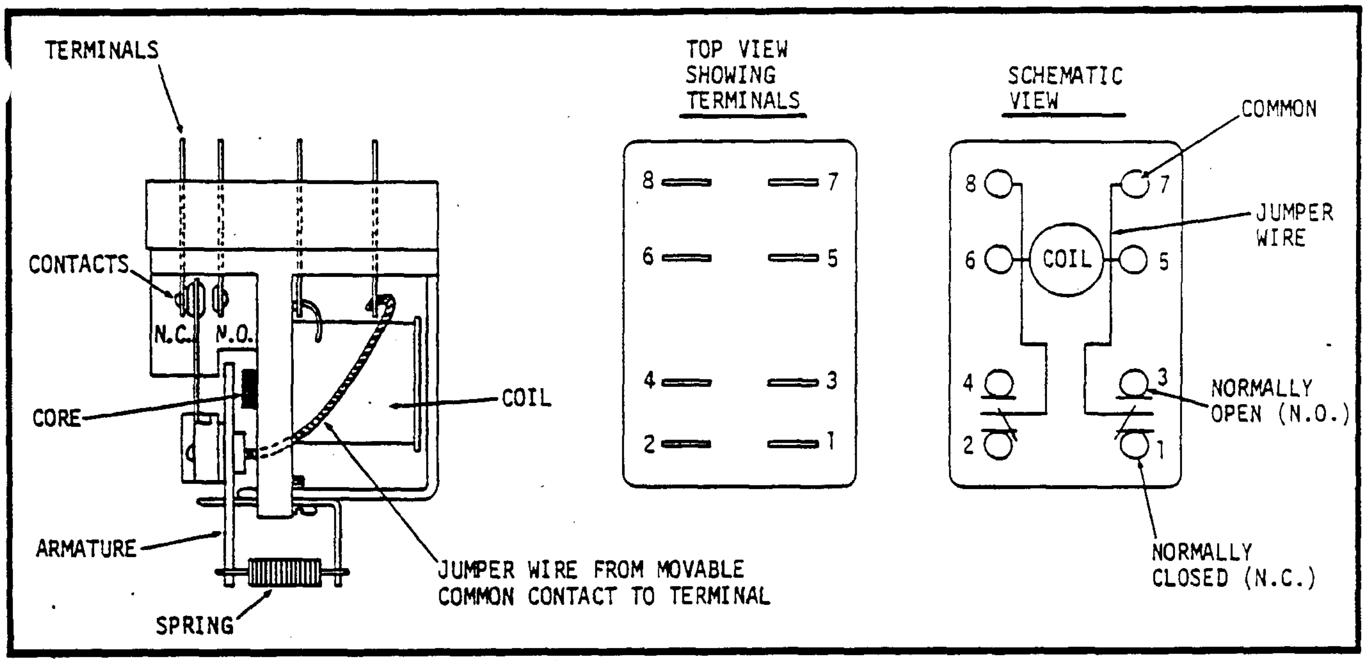


FIGURE 7 -- COMPONENTS OF A TYPICAL MULTIPLE CONTACT RELAY

A typical enclosed relay is depicted in Figure 5. The enclosure protects the contacts against the adverse effects of moisture and dust. Some of the relays used in controllers are not completely enclosed but have plastic shields over the contacts. Terminals are identified usually by numbers stamped next to the terminals as shown in Figure 5--these numbers also appear on the schematic portion of the wiring diagrams. Another commonly used enclosed type relay is the regulator relay which is a voltage sensing relay. These are preset to activate contacts at specific voltage levels to regulate battery charging. Figure 6 shows a typical starting solenoid or relay. These are generally used to control flow of heavy battery current during cranking. Cranking relays with the single terminal as shown are grounded thru the mounting brackets--cranking relays with two small terminals as shown schematically in Figure 6 are of the ungrounded type.

CRANKING CONTROL RELAY (CC): The unique function of relay CC is to disconnect at the proper moment the cranking circuit of exciter cranked plants. To provide this, a loop of heavy wire is placed next to the coil of the relay as shown below. During cranking, the magnetic flux around the wire cancels the flux of the coil to prevent movement of the relay armature. After the engine starts and exciter voltage becomes higher than voltage of the series field, current will reverse direction thru the loop allowing armature movement and resulting deactivation of the cranking circuit--this effect is described further on page 14. If the direction of the loop is incorrect, the contacts of relay CC will chatter.

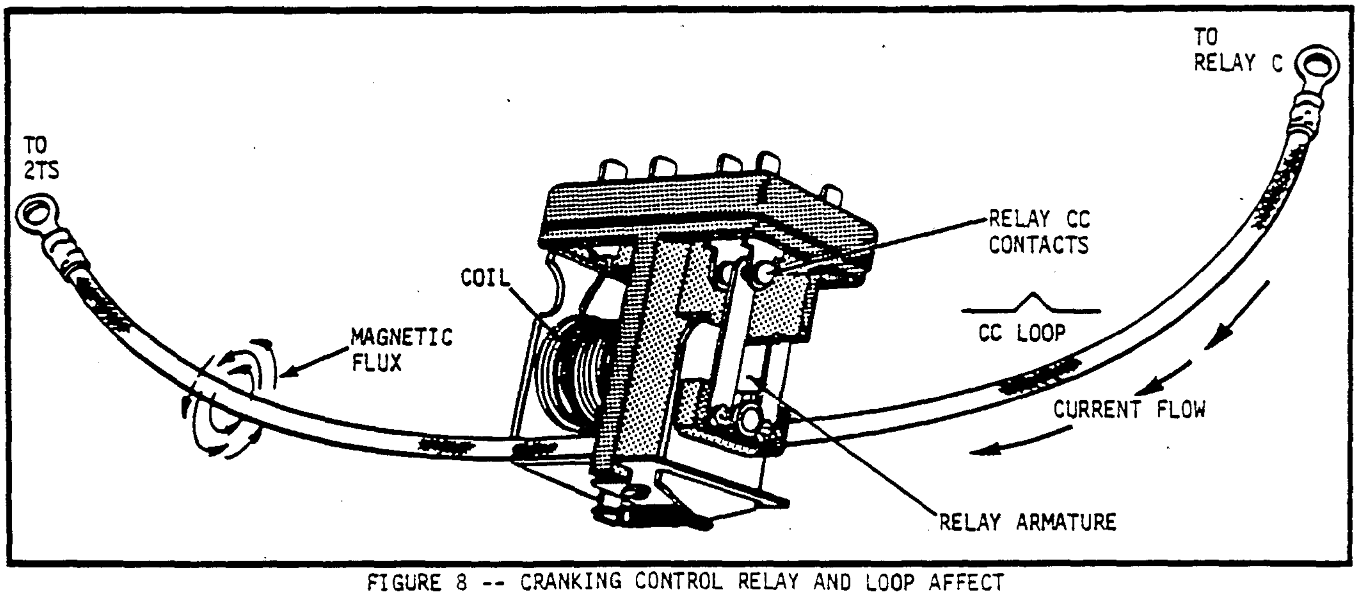


FIGURE 8 -- CRANKING CONTROL RELAY AND LOOP AFFECT

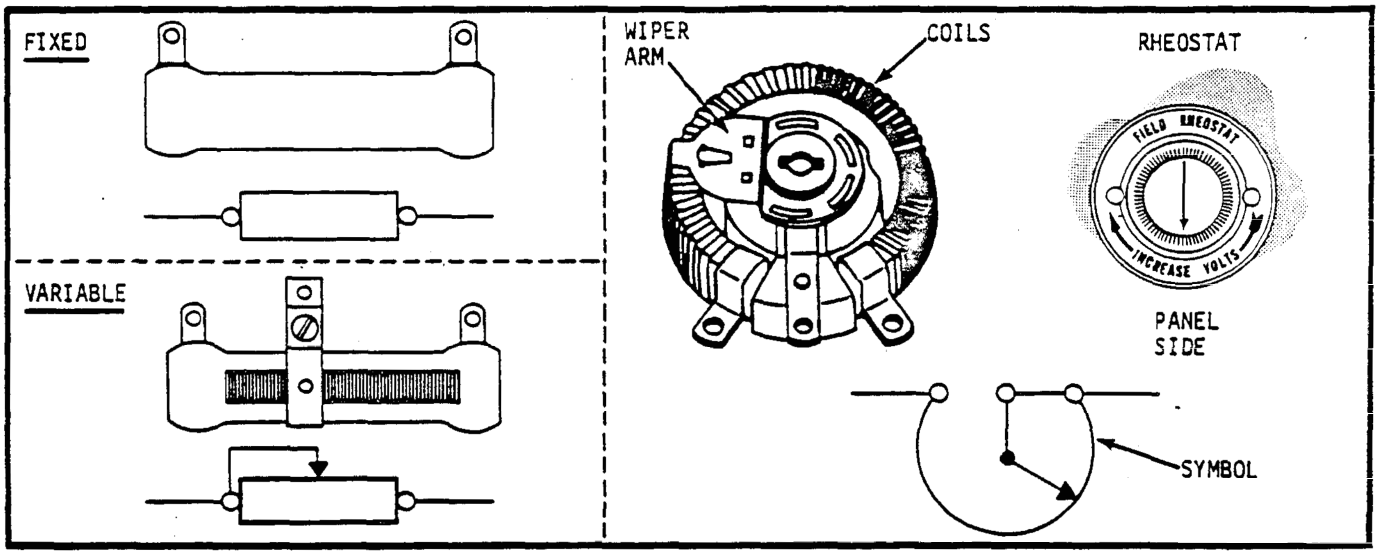


FIGURE 9 -- TYPICAL RESISTORS AND RHEOSTAT

RESISTORS

A resistor is inserted into a circuit to introduce resistance and thereby limit the amount of current flow. Resistance depends upon the length, cross sectional area and physical properties of a conductor. These factors are utilized in the construction of a resistor. Resistors used in controllers are usually wire or ribbon wound. Physical size of the resistor depends on the wattage rating, not the ohm value. For example, all 10 watt resistors are usually of the same physical size while 10 ohm resistors may be of widely varying size. Resistance in a circuit determines amount of current flow. Thus, a fixed resistor introduces a certain established resistance within the circuit. A variable resistor usually has some means of varying the length of the resistor element.

A rheostat is a form of variable resistor. Rheostats are usually wire wound and amount of resistance can be varied by a movable wiper arm. Control of resistance and of current is therefore achieved by varying the number of coils within which current is allowed to flow.

TRANSFORMERS

Transformers are devices usually used to increase (step-up) or decrease (step-down) voltage. A typical transformer consists of a metal core around which are wrapped two coils of wire called a primary and a secondary coil. Coils are placed opposite to each other so that voltage applied to one coil will be transmitted to the other through the process of electro-magnetic induction. By varying the number of turns in the coils, induced voltage can be either stepped-up or stepped-down as desired. In a step-up transformer, the secondary coil is provided with more turns than the primary. Power applied to the primary coil generates a magnetic field which cuts across the turns of the secondary coil and amplifies or steps-up voltage in direct ratio to the number of additional turns that the coils have. For example, if the primary coil consists of 4 turns and 10 volts are imposed on this coil, and the secondary coil consists of 8 turns, a voltage of 20 volts would be induced in the secondary coil.

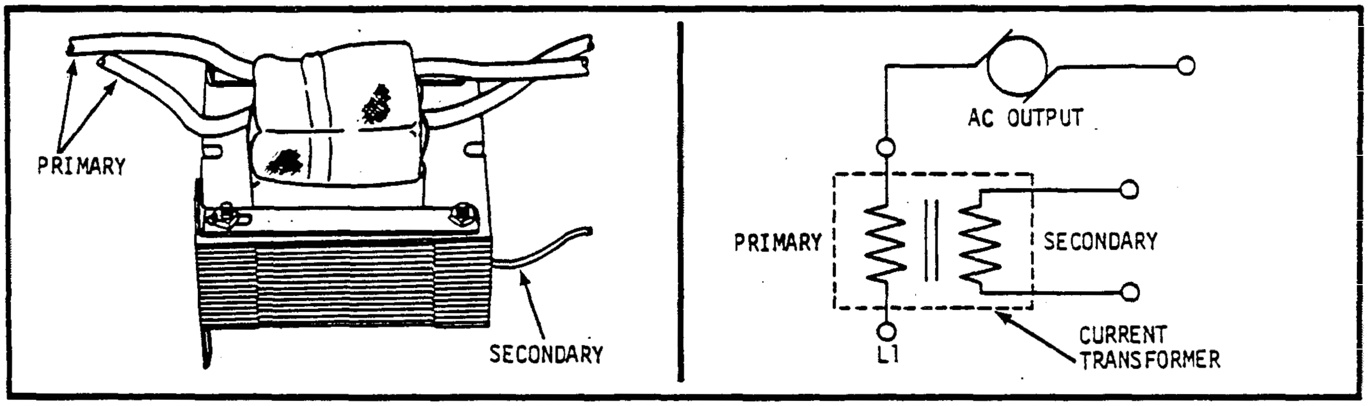


FIGURE 10 -- TYPICAL CURRENT TRANSFORMER AND SCHEMATIC

Most transformers in Kohler controllers are connected and used as current transformers. The primary is connected in series with the output of the generator load leads. The output of the secondary is thus in direct proportion to the load demand of the generator. Some have two primary windings--when replacing one of these, it is important to observe correct polarity so that one winding does not cancel the effect of the other.

RECTIFIERS

Rectifiers are used to convert alternating current to direct current. A simple rectifier consists of a thin film of metallic oxide which is imposed on a thicker plate of metal such as iron. Selenium is often used as the oxide in the construction of a rectifier.

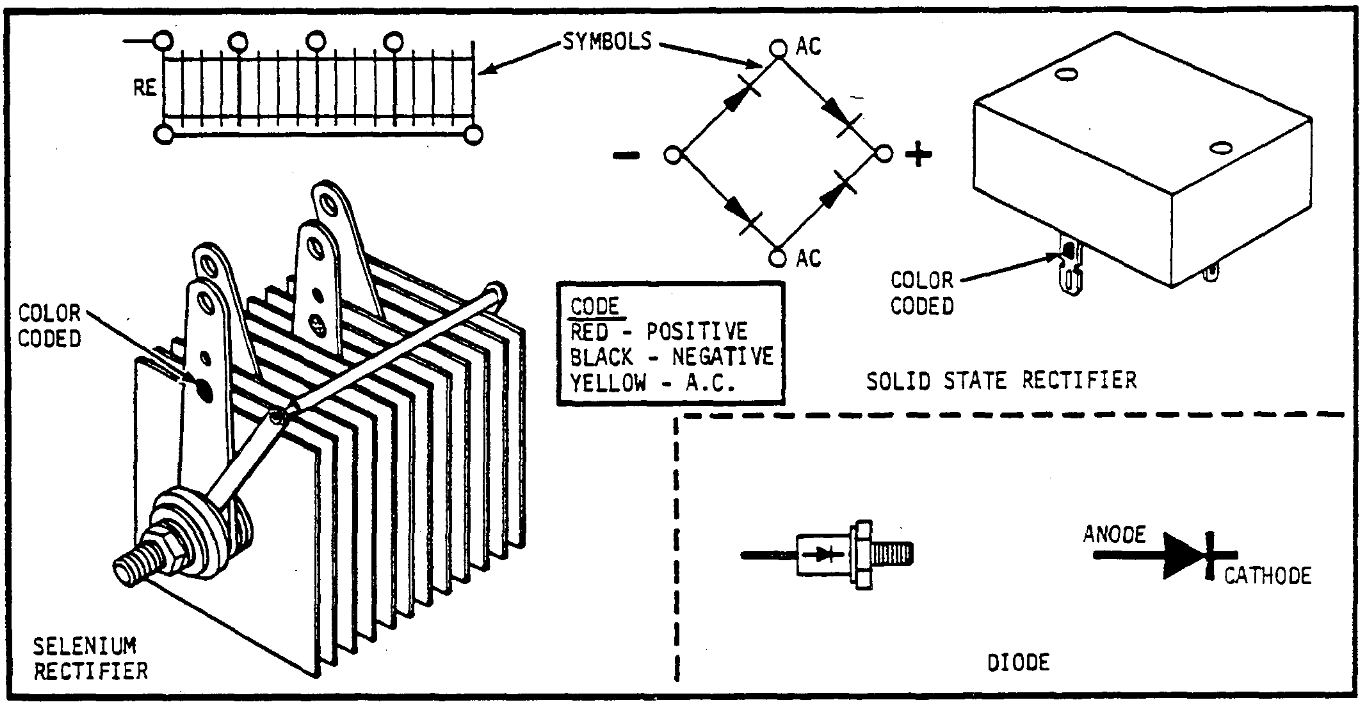


FIGURE 11 -- COMMON RECTIFIERS AND BLOCKING DIODE

When alternating current is applied to a rectifier, little resistance is offered to current flow in one direction while a very high resistance is offered in the opposite direction. For example: Current flows readily through the rectifier from the metal to the oxide, but from the oxide to the metal, very little or no current flows. The rectifier, therefore, allows one alternation of AC to flow but blocks the reverse alternation which results in flow of a pulsating direct current. This type of rectifier is often referred to as a blocking or half wave rectifier. The arrow used in its symbol indicates the direction current is allowed to flow.

Full wave rectifiers are also used in a Controller. A full wave rectifier utilizes both alternations of alternating current. By stacking a series of plates such as those used in the half wave rectifier and electrically bridging these plates, both alternations of the AC can be used to produce a smooth, uninterrupted flow of direct current. Full wave rectifiers are used to power circuits requiring a high current draw at a low voltage.

Condensers (Capacitors): Capacitors are sometimes referred to as condensers--they are, however, one and the same thing. Capacitors are electrical devices used to store energy within a circuit. A simple capacitor consists of two metal plates of good conducting ability separated by an insulator called a dielectric. The capacitor's ability to store energy is determined by the area and material of the plates, the distance between the plates and the type of dielectric used.

A capacitor in a DC circuit will allow current to flow only while the plates build up charge which is only momentarily. After the plates are fully charged, the capacitor then becomes an effective open circuit in DC. In AC circuits, the constant reversal of polarity causes the plates to charge in one direction, discharge and then charge in the opposite direction at regular intervals. In AC then, even though current does not actually flow through the dielectric, there is a constant flow to and from the plates.

Capacitors cause current to lead voltage and are used in AC circuits to neutralize the undesirable effects of lagging current or inductive reactance which causes poor efficiency and can overload the power source. Capacitors are also used in some cases to filter or block DC current from entering a circuit.

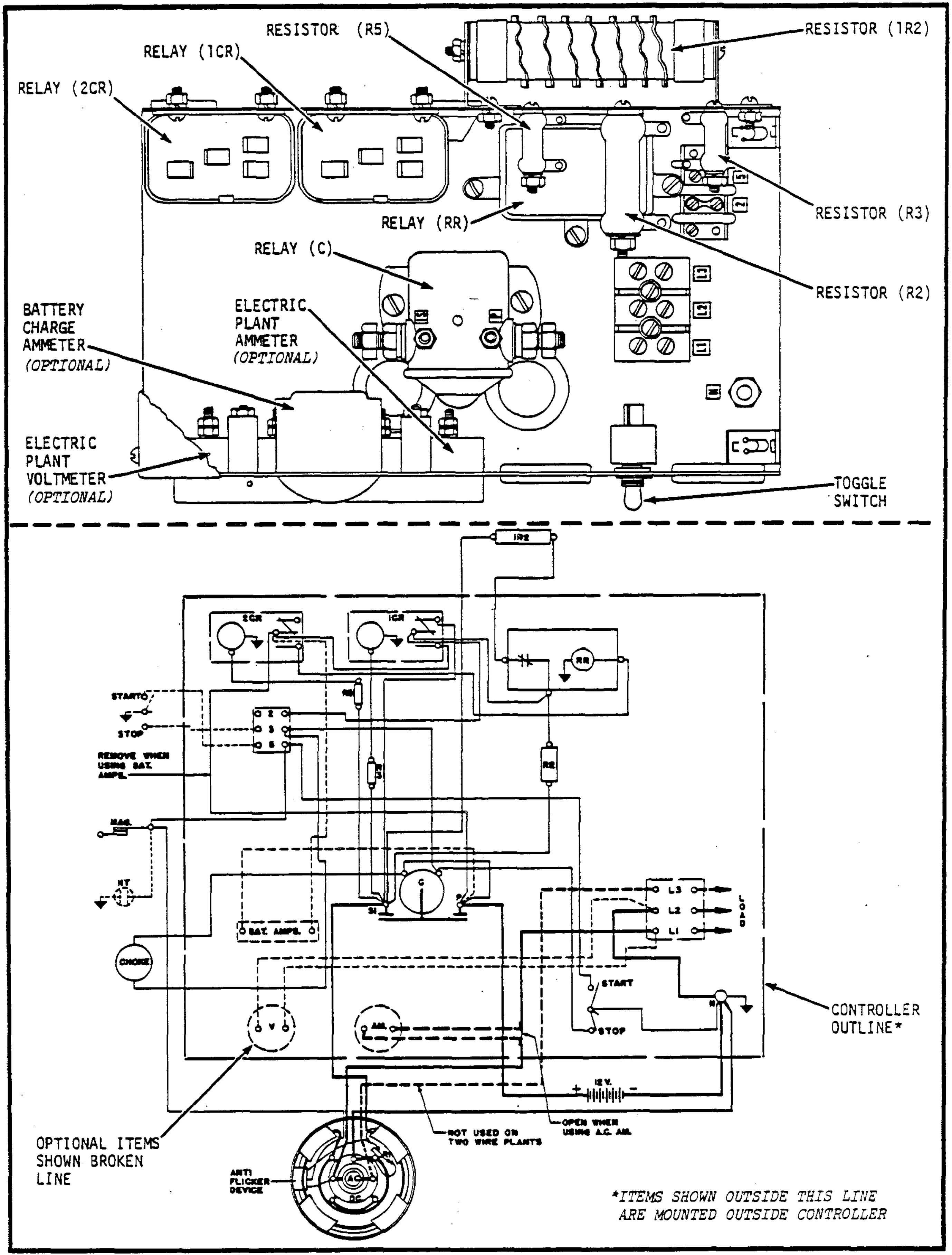


FIGURE 12 -- RELATIONSHIP OF CONTROLLER PARTS TO SCHEMATIC SECTION OF WIRING DIAGRAM

CONTROLLER CIRCUITS

Generator sets are supplied with Controller wiring diagrams that are usually divided into two sections. One section represents a pictorial view of the Controller and is used for locating components and wiring connections. Because of the complexity, it is difficult to analyze a circuit on this pictorial view. For this reason, another drawing, called a line diagram, is usually provided for trouble shooting or circuit analysis purposes.

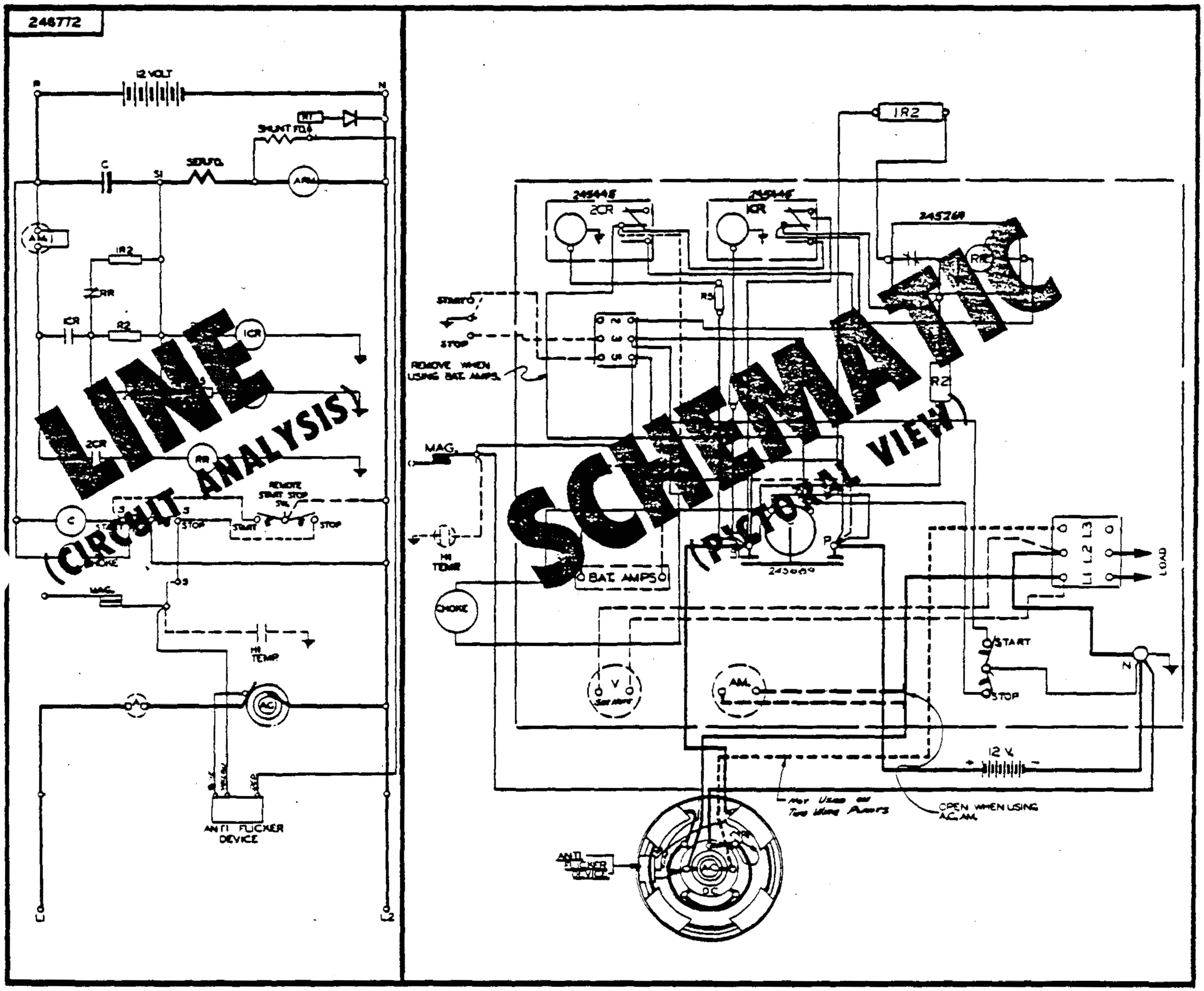


FIGURE 13 -- TYPICAL WIRING DIAGRAM SHOWING LINE AND SCHEMATIC VIEWS

CIRCUIT ANALYSIS

The line diagram schematically depicts the operational sequence of a Controller circuit. In tracing out a circuit, it must be remembered that a single relay may open or close two or more circuits simultaneously even though each circuit must be discussed separately. Components that are placed side by side in the actual Controller may be shown in remote areas of the diagram to simplify and make it easier to read and understand. Furthermore, relay and switch contacts are always shown in the normal, de-energized position. When tracing a circuit using Kohler diagrams, use the conventional theory of current flow which is from positive to negative.

While there are perhaps a few thousand different controller circuits, each performs certain basic functions. If these basic functions are understood, analysis of any one of the many circuits becomes easier. On the following pages, the line circuits of some typical plants are analyzed.

CIRCUIT ANALYSIS - REMOTE CONTROLLER

To become more familiar with the procedure in using a line diagram, we have selected diagrams from a Remote Controller. These represent many of the basic functions performed by Controllers.

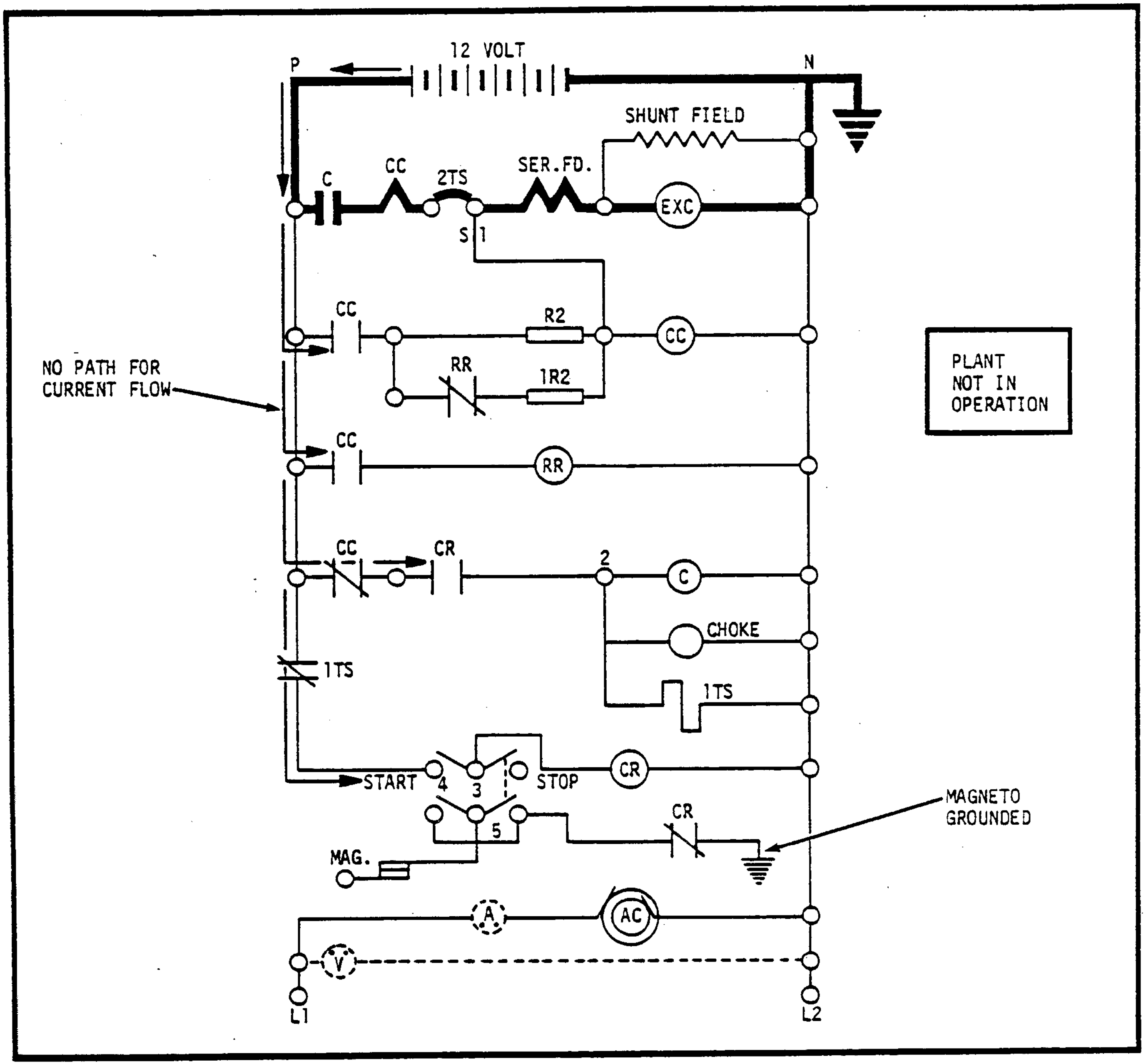


FIGURE 14 -- TYPICAL LINE DIAGRAM - REMOTE CONTROLLER PLANT

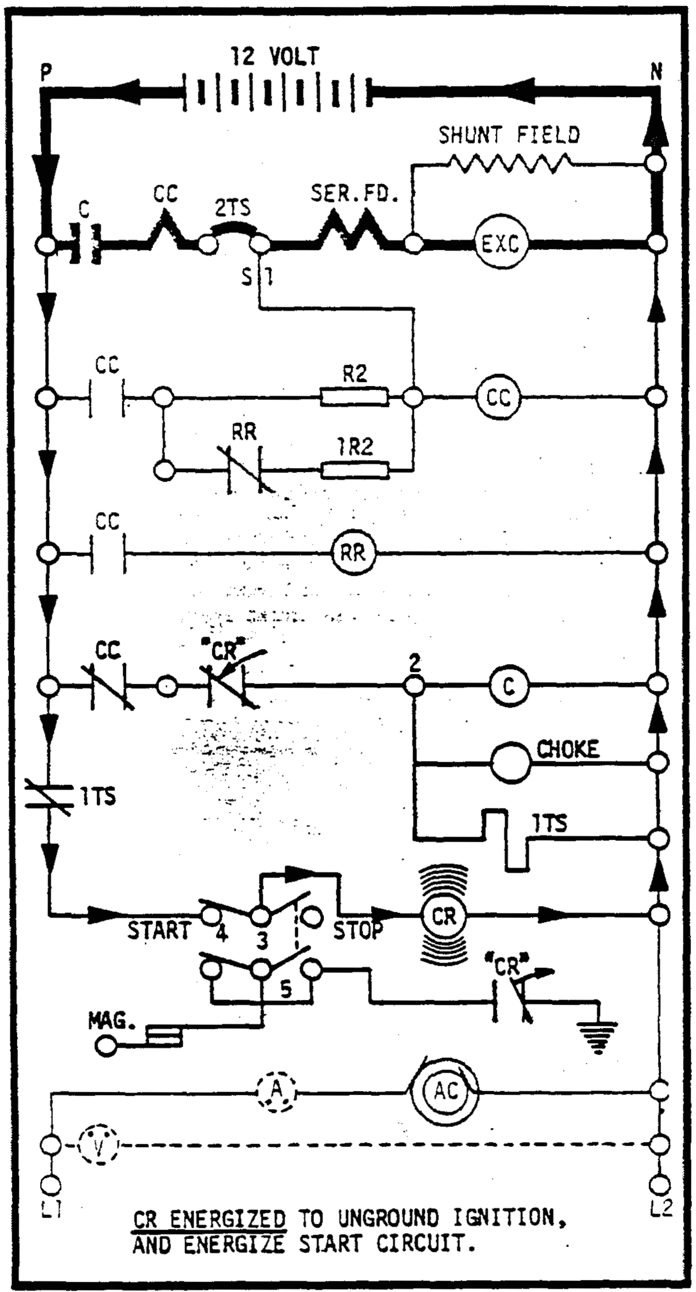
OPERATIONAL SEQUENCE

Figure 14 represents the complete line diagram for a typical Remote Controller equipped, exciter cranked generator set. The Controller automatically regulates the starting, running and stopping procedure. It also controls charging of the storage battery when the unit is running.

The first circuit prepares the generator set for starting.

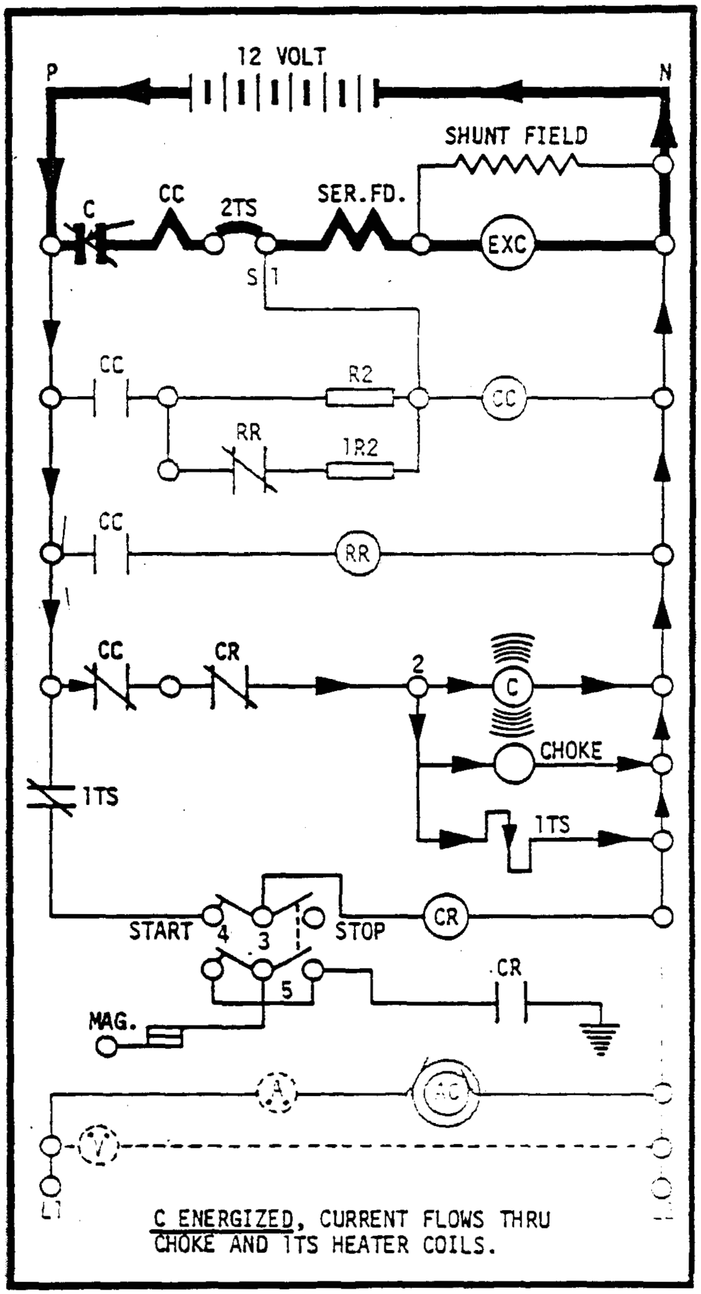
1st Circuit: As shown in Figure 15, moving the start-stop switch to the START position completes an electrical circuit. On this Controller, this is done from a remote location. Current then flows from the positive terminal of the battery through the now closed start-stop switch, through relay CR and back to the negative side of the battery.

Relay CR has two sets of contacts; one set is normally open, the other normally closed. Current flowing through CR causes the normally closed contacts to open which ungrounds the magneto and allows the ignition system to function. The other (normally open) set closes to complete the second circuit.



CR ENERGIZED TO UNGROUND IGNITION, AND ENERGIZE START CIRCUIT.

FIGURE 15 -- CRANKING PREPARATION - 1ST CIRCUIT

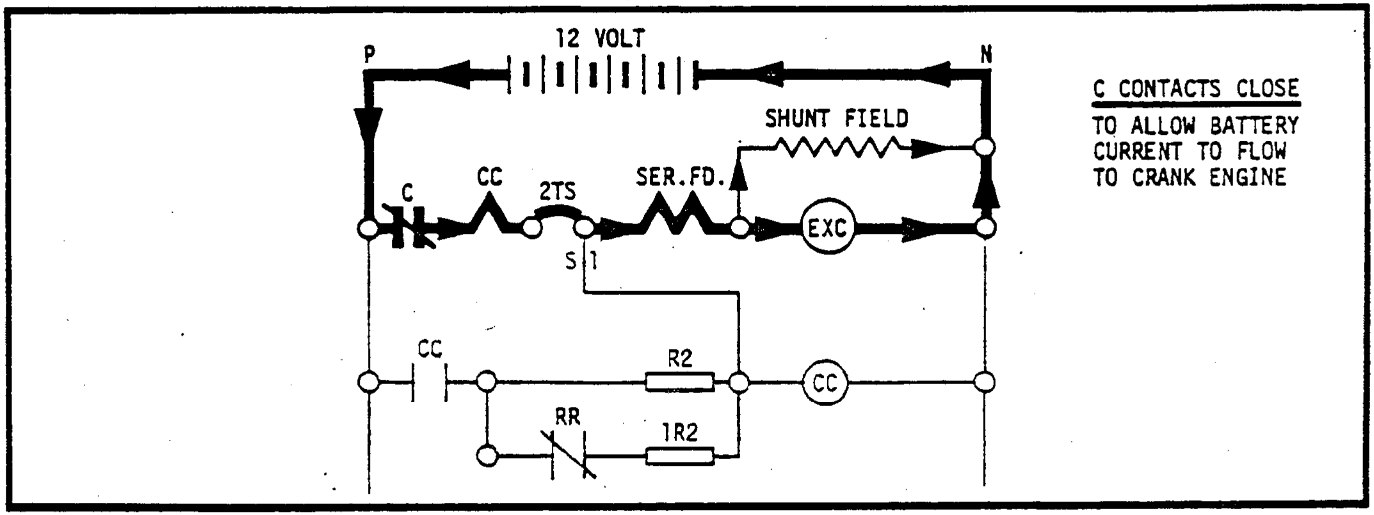


C ENERGIZED, CURRENT FLOWS THRU CHOKE AND 1TS HEATER COILS.

FIGURE 16 -- CRANKING PREPARATION - 2ND CIRCUIT

2nd Circuit: As contacts CR close, current flows from the battery through the normally closed contacts CC, through CR, relay C, then back to the negative terminal of the battery. Current also activates the electric choke and thermal switch 1TS in completing this circuit.

With the ignition system, choke and overcrank thermal switch activated, the unit is now ready to crank for starting. The contacts of relay C close to complete the third or cranking circuit.

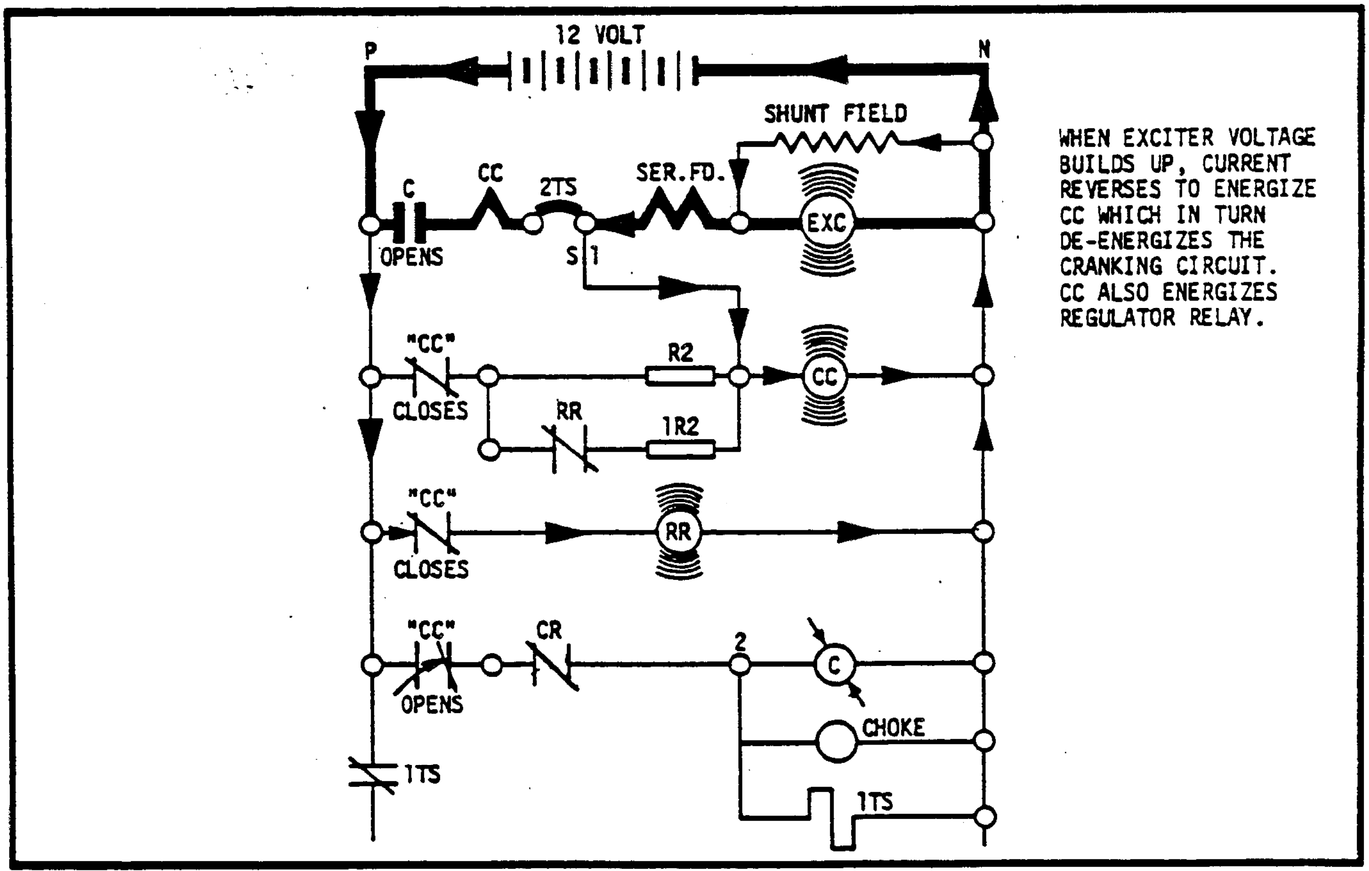


C CONTACTS CLOSE
TO ALLOW BATTERY
CURRENT TO FLOW
TO CRANK ENGINE

FIGURE 17 -- CRANKING CIRCUIT ENERGIZED

3rd Circuit: Energizing relay C, which is the cranking relay, closes contact C and allows battery current to flow through contacts C, CC loop, thermal relay 2TS, the series field, shunt field, exciter armature and back to the negative side of the battery. A small current also flows thru coil of relay CC; however, this does not energize at this time. Current through this circuit causes the exciter to act as a motor and crank the engine for starting.

Relay CC consists of two coils of wire. The coil of heavy wire, which is wound through the frame of the relay, is represented by ⁀ symbol in the diagram. The main coil of relay CC is connected to S1. As long as current flows from the battery through the cranking circuit, a magnetic field will be induced in the CC loop while at the same time, voltage which is building up in the exciter energizes the other coil of relay CC. The two coils are wound so that their magnetic fields oppose each other. While their fields oppose, there is insufficient force to operate the normally open contacts CC. When the engine starts to run, the exciter current reverses direction and the magnetic fields of the coils combine which energizes coil of relay CC.



WHEN EXCITER VOLTAGE
BUILDS UP, CURRENT
REVERSES TO ENERGIZE
CC WHICH IN TURN
DE-ENERGIZES THE
CRANKING CIRCUIT.
CC ALSO ENERGIZES
REGULATOR RELAY.

FIGURE 18 -- CRANKING CIRCUIT DE-ENERGIZED

Before proceeding further, it should be mentioned here that in the event the engine will turn over but fails to start within 30-60 seconds, thermal relay 1TS will disconnect cranking to prevent battery exhaustion. If the plant fails to crank because of locked rotor or other causes, thermal relay 2TS will trip after approximately 10 seconds.

Coil CC has three sets of contacts - two normally open and one normally closed. Although all are activated simultaneously, we will have to discuss them separately. Since the engine is now running and the set producing energy, current is no longer necessary through the series field since it is needed only for cranking the exciter. Energizing coil CC causes the set of normally closed contacts to open. As illustrated, this breaks the 2nd circuit, which in turn de-energizes relay C, the electric choke and thermal switch 1TS. As relay C is de-energized, its contacts open to break the cranking circuit and de-activate the series field. Returning to the two normally open contacts of relay CC, we find that as the contacts close, they complete two separate circuits that serve to re-charge and regulate the battery.

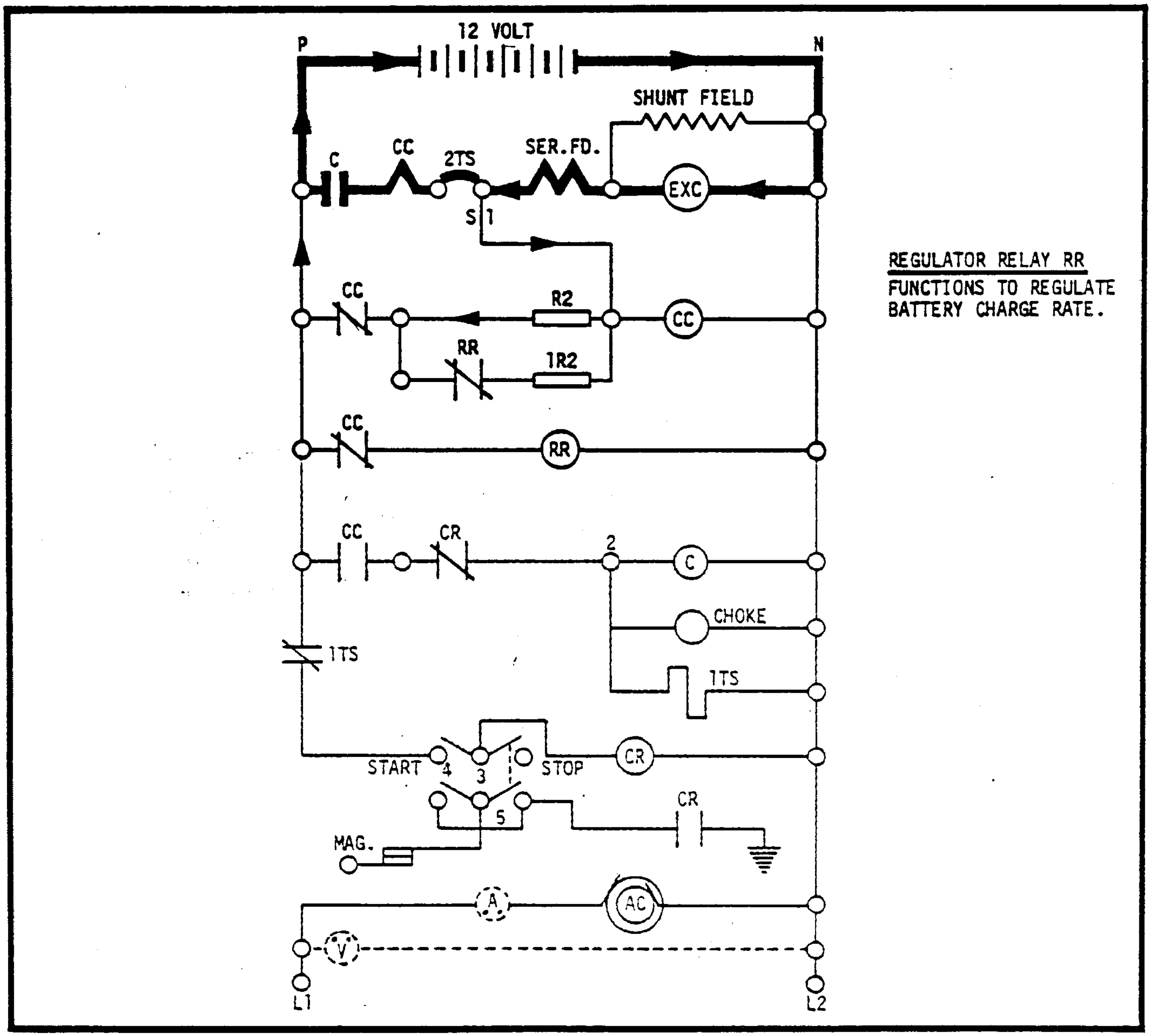
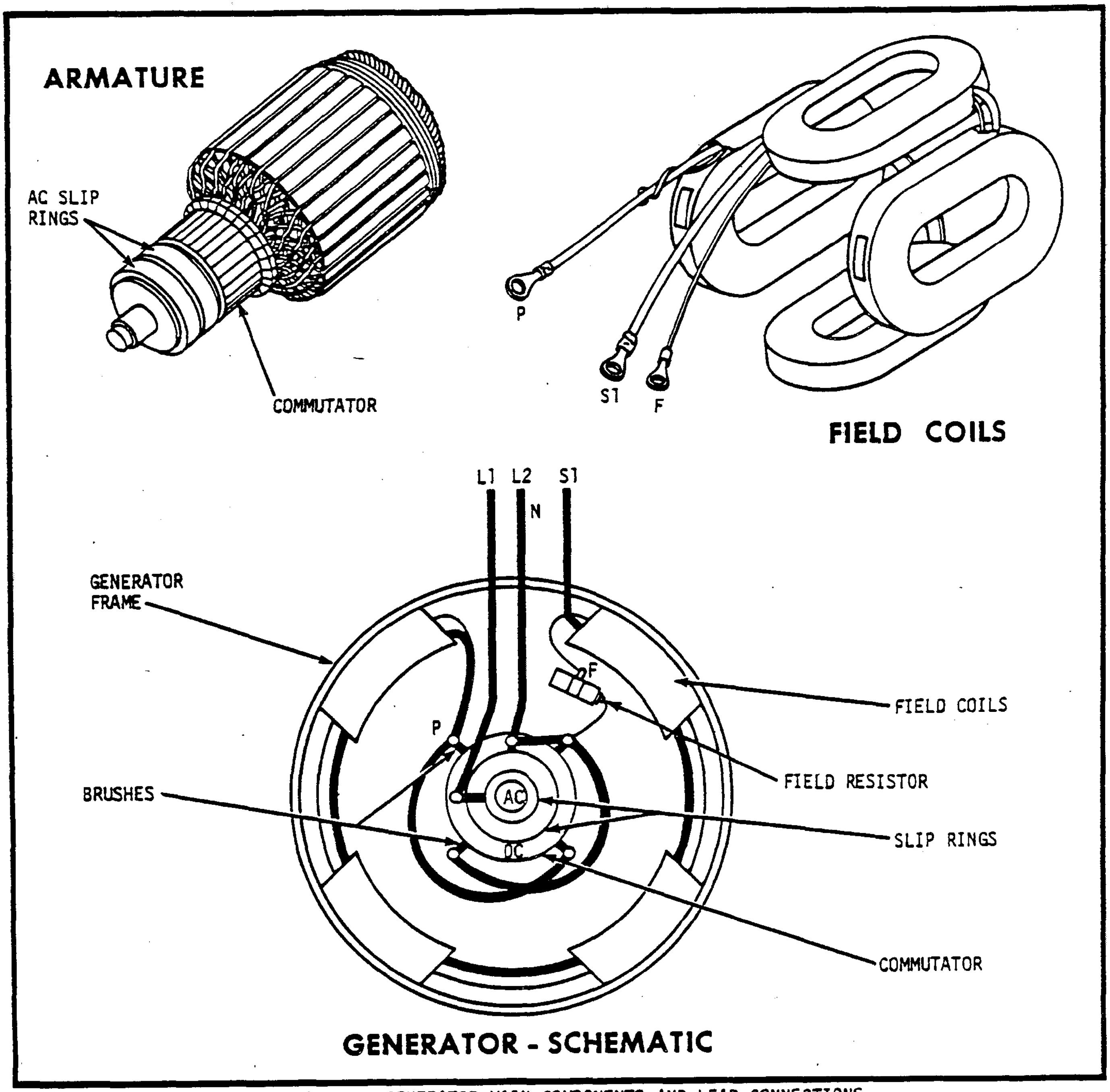


FIGURE 19 -- BATTERY CHARGING CIRCUIT

Battery charging current produced by the exciter flows through lead S1, through the low current limiting resistor, through the battery and back to the exciter. It also flows through the high charge limiting resistor 1R2. Resistor R2 limits current flow to approximately 1 amp while 1R2 allows approximately 9 amp.

Even though current is flowing through relay RR, it will not energize to open its normally closed contacts until the voltage gets up to about 14. 5 volts. It is therefore the voltage sensing relay. When RR does energize and its contacts open, current can no longer flow through resistor 1R2. When voltage drops below 12. 5, this relay de-energizes and again completes the circuit through 1R2.


ARMATURE

FIELD COILS

GENERATOR - SCHEMATIC

FIGURE 20 -- GENERATOR MAIN COMPONENTS AND LEAD CONNECTIONS

Stopping the plant is accomplished by breaking the initial circuit. Moving the start-stop switch to the stop position de-energizes relay CR which in turn closes contacts CR in the ignition circuit and grounds the magneto.

CIRCUIT ANALYSIS - PUSH BUTTON PLANTS

Except for starting procedure, analysis of a push button plant is very similar to that of the previously analyzed remote controller. The differences are as follows.

When the start switch is held in the START position, current flows from the positive side of the battery, thru solenoid C and choke coil and thru the start switch to ground. As contacts of C close, current flows to the armature causing it to motor and crank the engine. When the engine starts, the switch must be released to break the cranking circuit--the momentary contact type switch returns to the center, or run position, when released. To stop, the switch must be held in the STOP position until the plant comes to a complete halt. This position connects the magneto to ground.

CIRCUIT ANAYSIS - AUTOMATIC PLANTS

The controller on an automatic plant must sense when a load demand is present, start the plant, connect it to the load and keep it operating as long as the load remains then shut the plant down when the load is removed. To accomplish automatic operation, the automatic controller includes components not found in other types of controllers. Items such as the load relay, transformer TR1 and additional control relays allow automatic operation.

Most automatic controller plants will start and operate on a load demand of about 60 watts although certain models require approximately a 100 watt load. Loads of less than 60 watts may be sufficient to start an automatic plant; however, current draw will not be sufficient to keep the plant running. Low current devices such as doorbell transformers, some refrigerator defroster devices, electric clocks, etc., do not present sufficient load to start an automatic plant. A refrigerator defroster may, however, draw enough current to keep a plant operating--check for such residual loads if an automatic plant does not shut down properly. A residual load as low as 25 watts may be sufficient to keep the plant running.

The operational sequence of a typical 2 wire automatic and a typical 3 wire automatic plant are traced separately on the following pages.

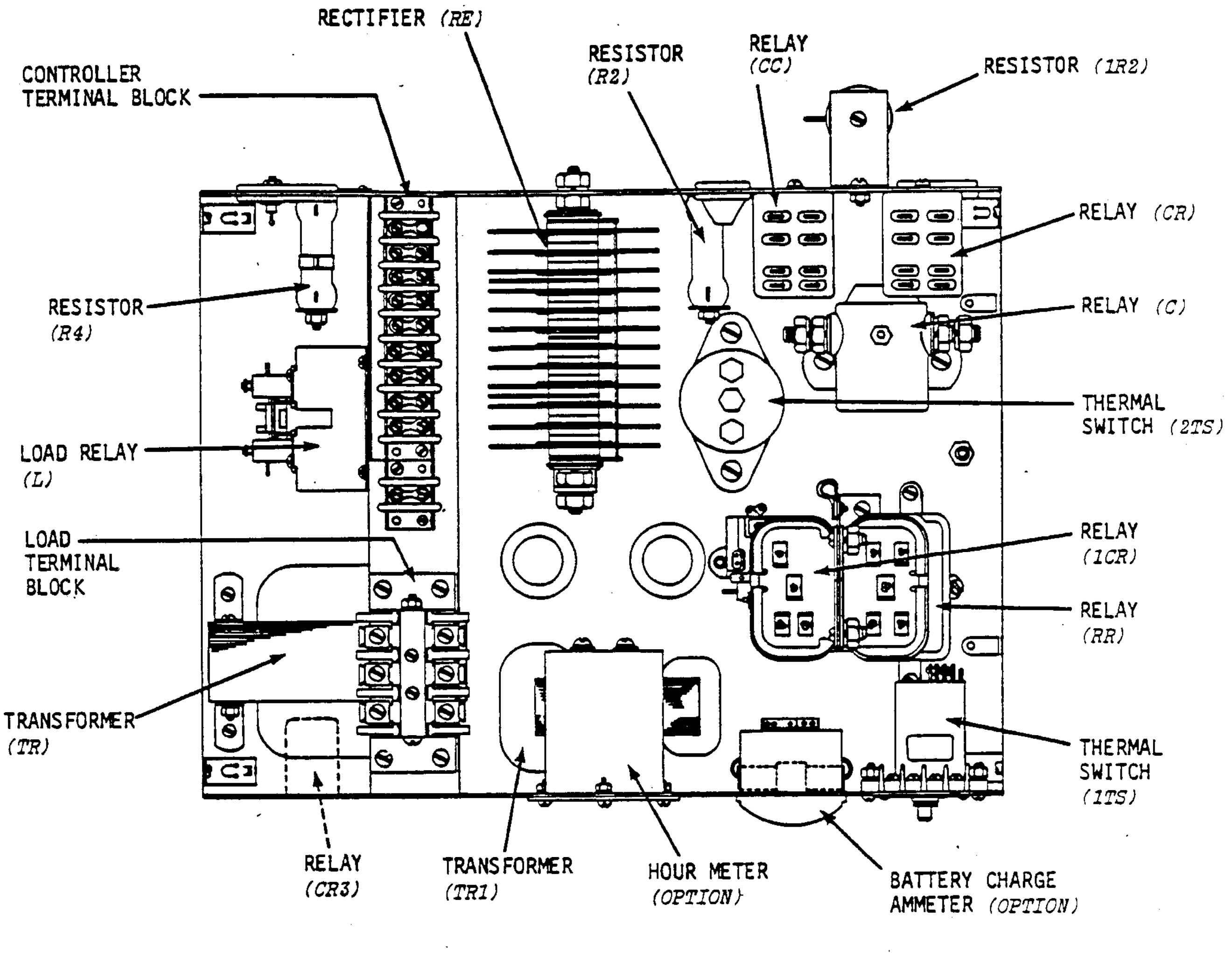


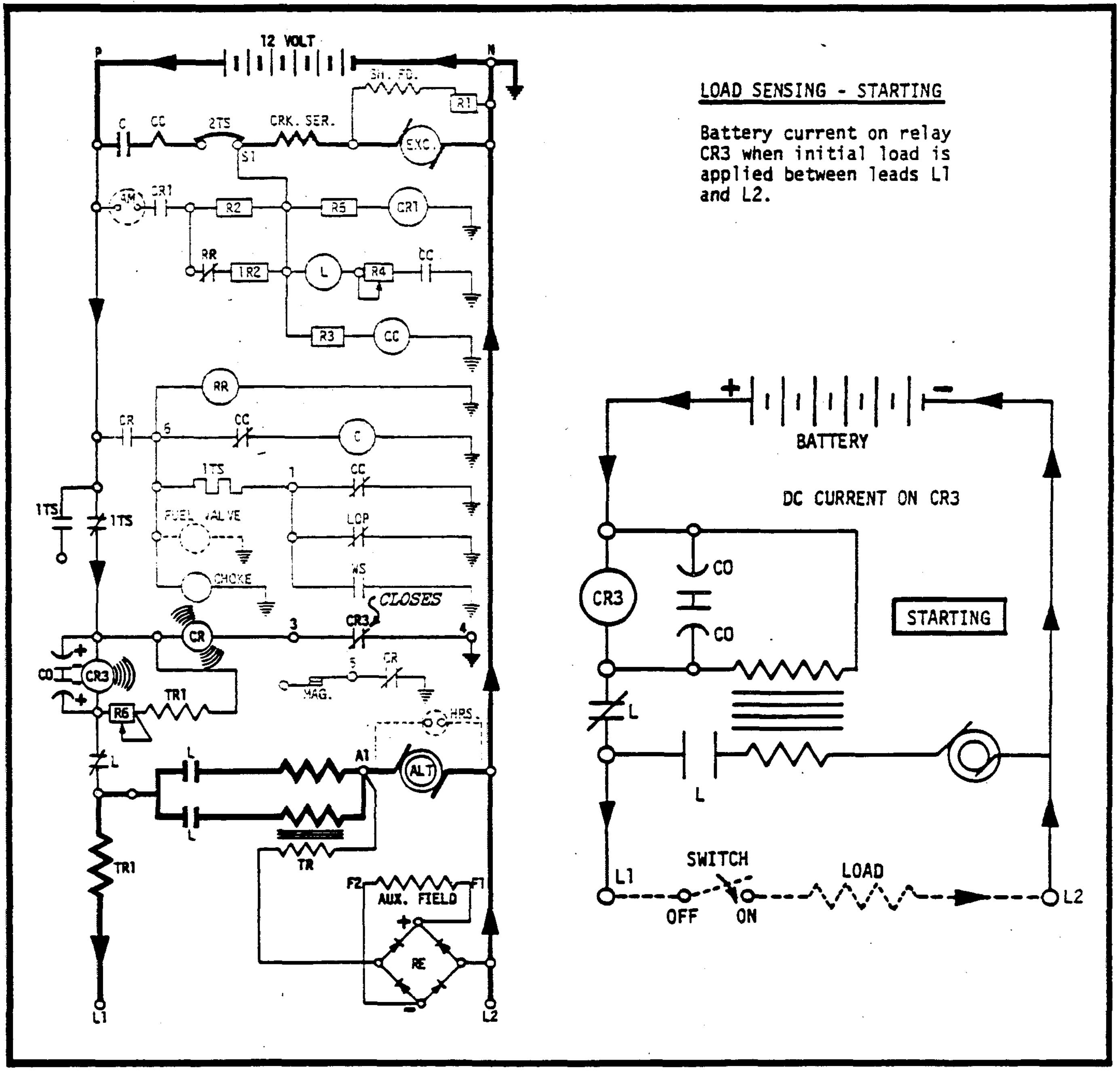
FIGURE 21 -- COMPONENTS OF A TYPICAL AUTOMATIC CONTROLLER

2 WIRE AUTOMATIC PLANTS

120 volt alternating current is available between output leads L1 and L2 on 2 wire automatic plants. Connecting a low resistance load between L1 and L2 completes a path allowing battery current to flow thru the coil of control relay CR3 causing it to energize or close its contacts which, in turn, completes a circuit thru relay CR allowing the plant to crank. The cranking sequence is the same as described previously for the remote controller.

After the engine starts and comes up to speed, the CC relay coil becomes energized to close its contacts allowing exciter voltage to energize the coil of load relay L. The load relay contacts then transfer from their normal position and alternating current from the generator will be applied thru the primary windings of transformer TR1 to the load. The normally closed contacts of relay L will now open to disrupt the path for battery current to flow to relay CR3.

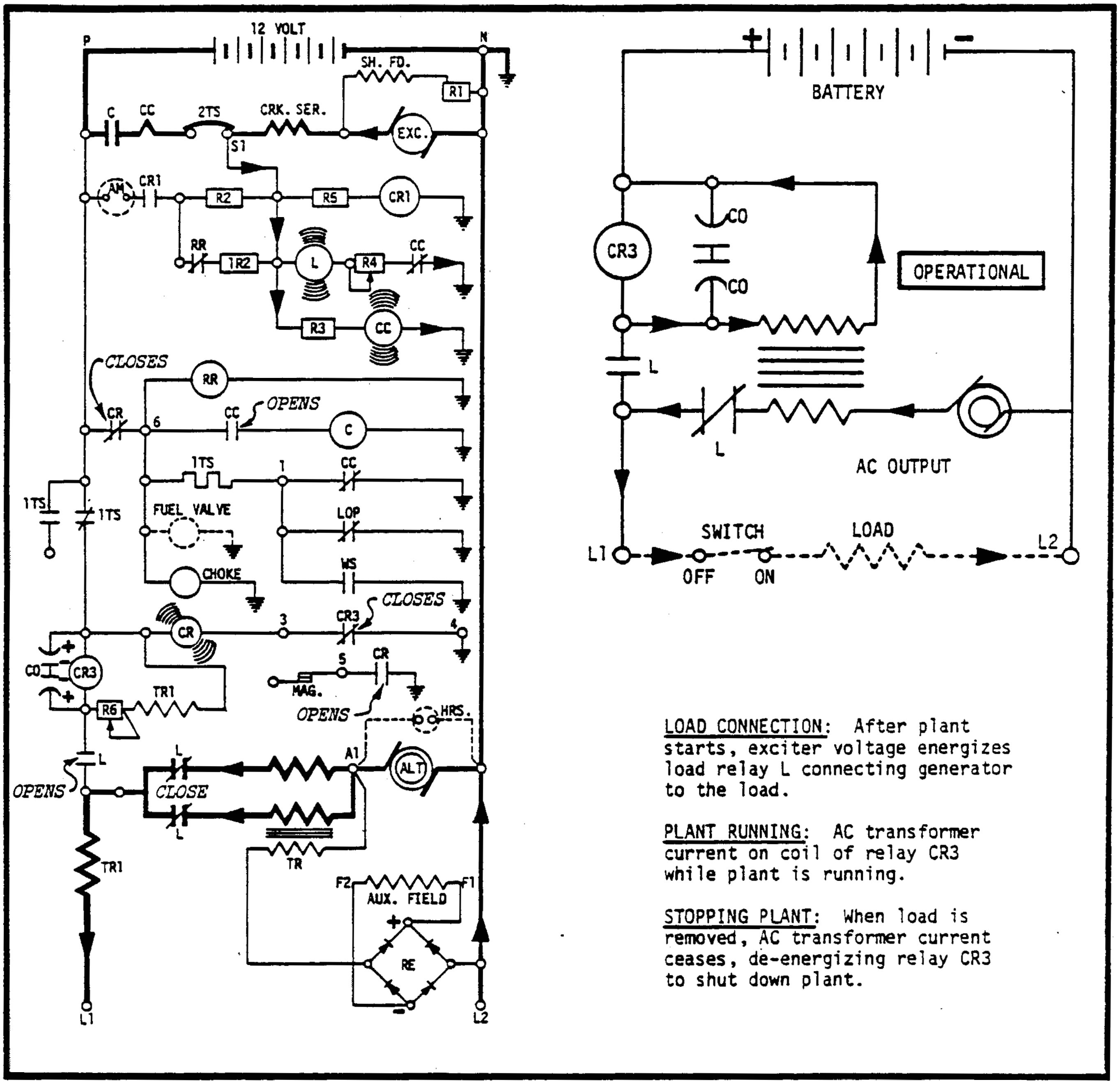
Resistor R4, which is in series with the coil of relay L, is adjusted to insure that exciter voltage must reach about 90% of normal before relay L can be energized and current furnished to the load.



LOAD SENSING - STARTING

Battery current on relay CR3 when initial load is applied between leads L1 and L2.

FIGURE 22 -- LOAD SENSING, STARTING OF A TYPICAL 2 WIRE AUTOMATIC



LOAD CONNECTION: After plant starts, exciter voltage energizes load relay L connecting generator to the load.

PLANT RUNNING: AC transformer current on coil of relay CR3 while plant is running.

STOPPING PLANT: When load is removed, AC transformer current ceases, de-energizing relay CR3 to shut down plant.

FIGURE 23 -- OPERATIONAL SEQUENCE OF A TYPICAL 2 WIRE AUTOMATIC PLANT

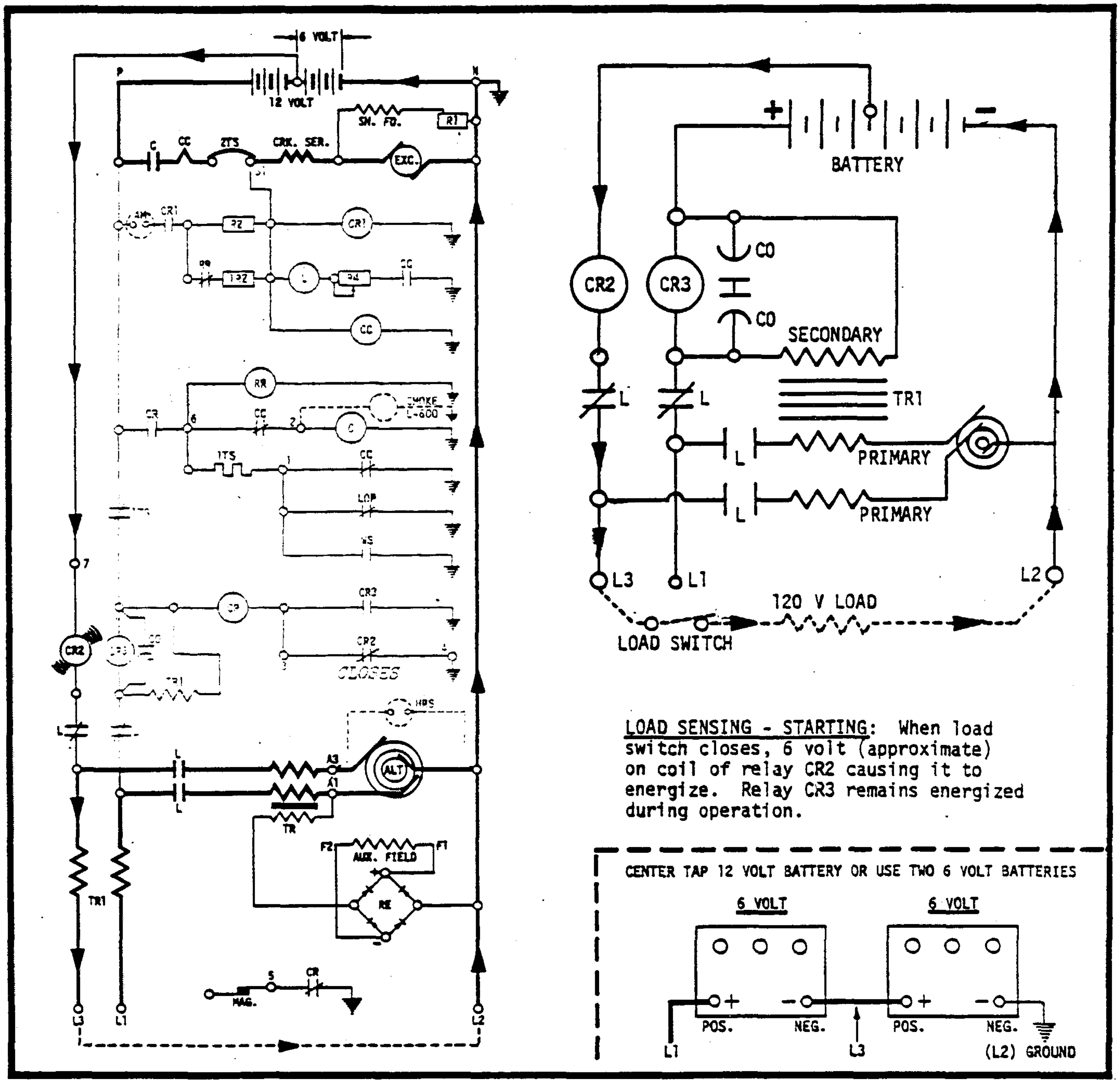
As alternating current flows thru the load, AC also flows thru the primary of transformer TR1 inducing a proportional amount of current flow through the secondary windings of TR1. This secondary current is used to keep relay CR3 energized. A minimum load of 60 watts is needed to keep CR3 energized. When load is disconnected by opening of a switch, current flow thru windings of TR1 ceases allowing relay CR3 to de-energize. This, in turn, disrupts current flow to the coil of relay CR causing the magneto to be grounded to stop the engine.

3 WIRE AUTOMATIC PLANTS

The 120/240 volt, single phase plants will start when load is applied between any combination of load leads providing the starting battery is properly center tapped. To start, 3 wire plants must have 6 volts available between L1 and L3. This can be accomplished by center tapping a 12 volt battery provided the cell connectors are exposed or can be easily detected. If center tapping of a 12 volt battery is impractical, two 6 volt batteries can be used and connected as shown in the inset on Figure 24.
The circuit analysis varies when load is connected to different load leads--these are discussed separately in the following.

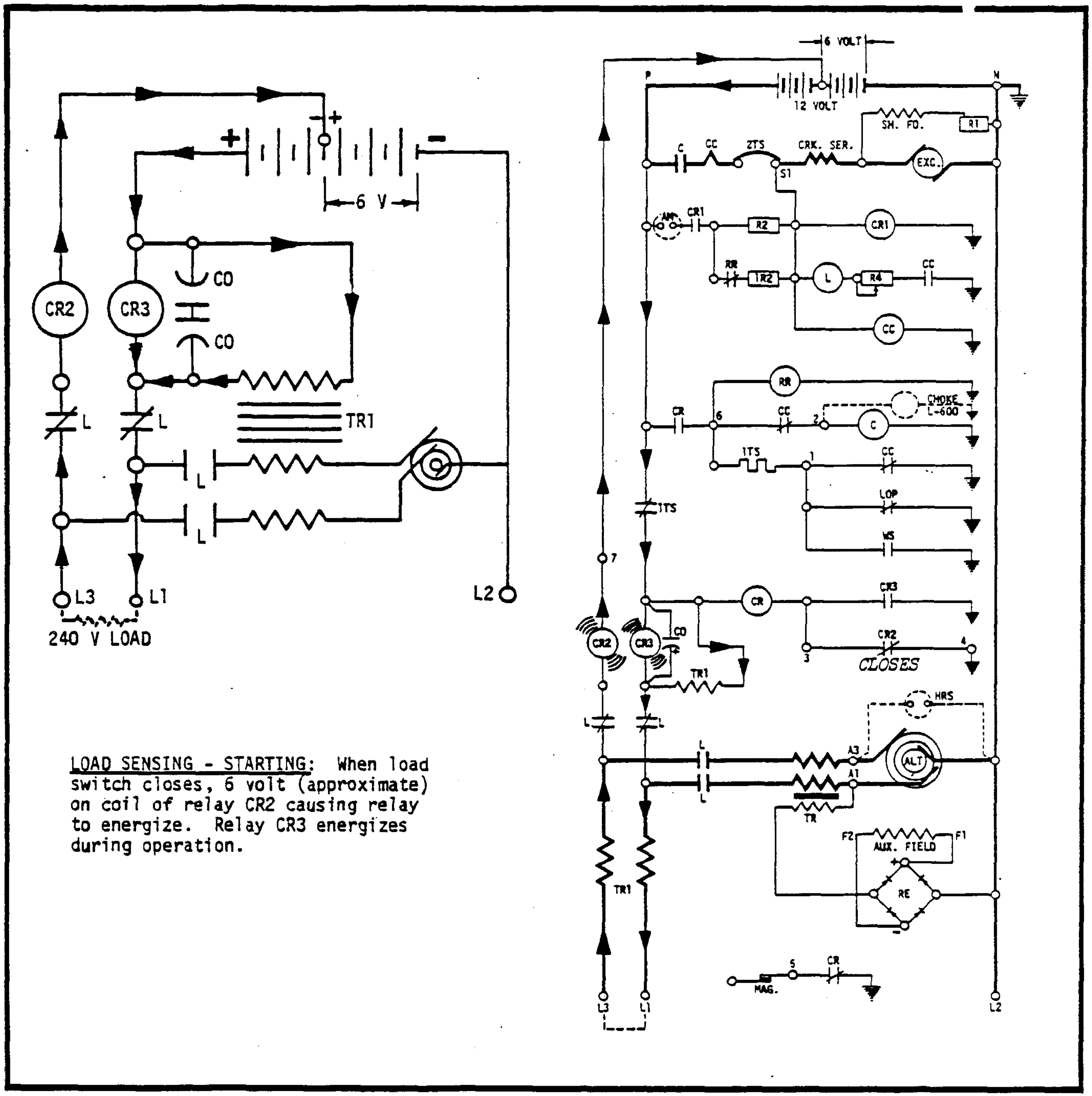
LOAD BETWEEN L1 and L2: 120 Volt AC is available when load is connected between L1 and L2 on 3 wire single phase plants. When connected this way, current can flow from the positive side of the 12 volt battery thru 1TS contacts, thru coil of relay CR3 thru the normally closed contacts of load relay L, thru the primary winding of transformer TR1, thru the load and back to the negative side of the battery to complete the circuit. As long as a load remains, current flowing thru transformer TR1 will keep relay CR3 energized to maintain operation. When the load switches off, CR3 de-energizes to allow the plant to shut down.

LOAD BETWEEN L3 and L2: 120 Volt AC is also available between L3 and L2 on 3 wire automatic plants. 6 volt battery current is required for starting when connected this way. When load switch is closed, current flows from the center tap or positive terminal of one of the 6 volt batteries, thru relay CR2, thru the normally closed contacts of load relay L, thru primary of transformer TR1, thru the load and back to the negative side of the battery to complete the 6 volt circuit. Relay CR2, which is a 6 volt relay, must remain energized to sustain operation with this connection.



LOAD SENSING - STARTING: When load switch closes, 6 volt (approximate) on coil of relay CR2 causing it to energize. Relay CR3 remains energized during operation.

FIGURE 24 -- TYPICAL 3 WIRE AUTOMATIC PLANT WITH LOAD BETWEEN L3 & L2



LOAD SENSING - STARTING: When load switch closes, 6 volt (approximate) on coil of relay CR2 causing relay to energize. Relay CR3 energizes during operation.

FIGURE 25 -- TYPICAL 3 WIRE AUTOMATIC PLANT WITH LOAD BETWEEN L3 & L1

LOAD BETWEEN L3 and L1: 240 Volt AC is obtained between leads L3 and L1. This connection also requires 6 volts to energize relay CR2. When connected this way, current can flow from the positive side of the battery thru the normally closed contacts of 1TS, thru coil of relay CR3 and secondary windings of transformer TR1, thru the primary windings of TR1, thru the load, thru the second primary winding of TR1, thru the normally closed contacts of relay L, thru the coil of relay CR2 and back to the center tap completing a 6 volt circuit.

The 120/240 volt single phase plants use a transformer with a double primary winding with a common secondary so that whenever current flows thru either of the primary windings, current will also flow thru the secondary to allow automatic operation thru either relay CR2 or CR3. No matter which relay is energized to start, however, only relay CR3 will remain energized during operation.

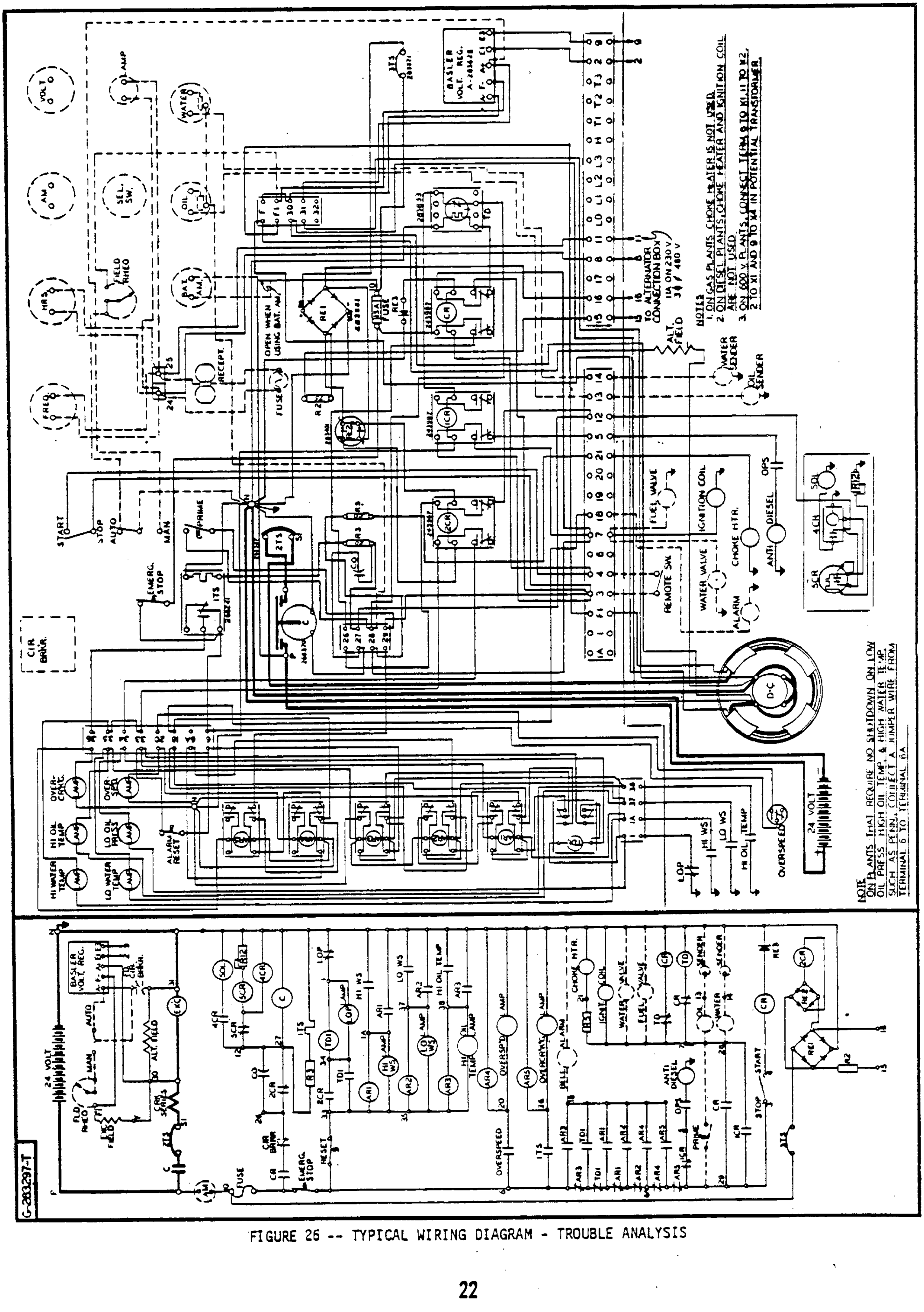


FIGURE 26 -- TYPICAL WIRING DIAGRAM - TROUBLE ANALYSIS

TROUBLE SHOOTING

The wiring diagram is an extremely valuable aid in locating and correcting malfunctions caused by faulty operation of Controller components. Another valuable tool is the multi-tester or as it is commonly referred to, the Volt-Ohmmeter. Current, voltage and resistance values can be read with this instrument. When measuring current flow (amperes), the Volt-Ohmmeter is connected in series with the circuit. When used as a Voltmeter, it is connected across the circuit. Before resistance readings (ohms) are taken, the power to the circuit must be removed and all parallel circuits must be disconnected.

Even with larger plants having more complex and complicated controller wiring diagrams, it is still fairly easy to locate malfunctions. By the process of elimination, the actual trouble can be quickly pinpointed. To illustrate this, let us use Wiring Diagram G-283297-T (on opposite page) and simulate, then locate some troubles that might occur.

Assume that this plant cranks but fails to start. The first thing to look for would be poor condition of the battery or loose connections at the battery terminals. Under these conditions, the cranking speed attained may be too low to allow starting.

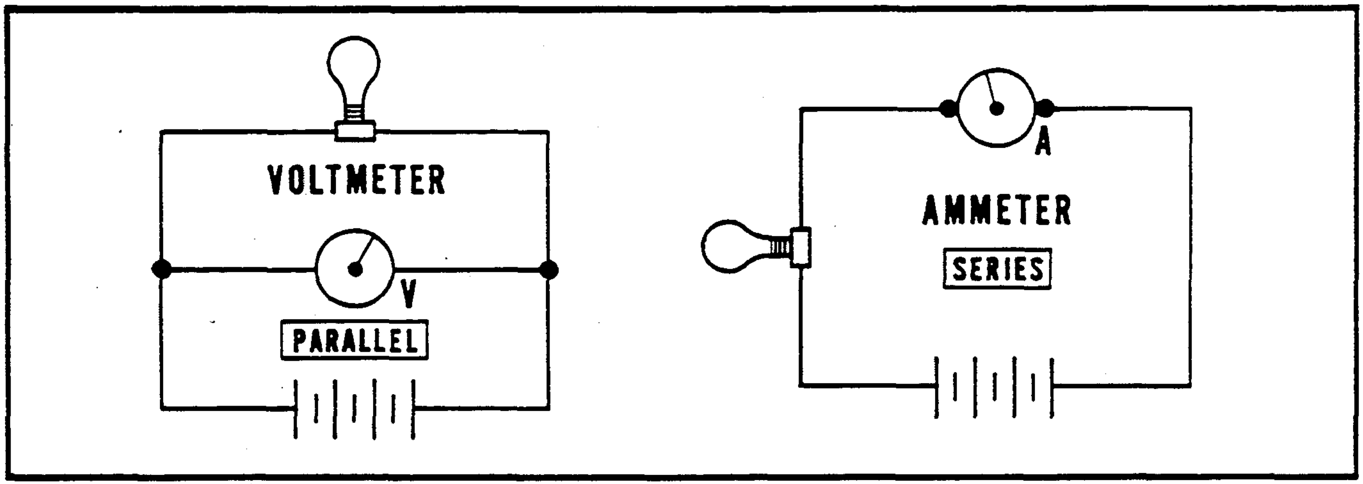


FIGURE 27 -- VOLTMETER AND AMMETER CONNECTIONS

If the battery and connections "check out", we have to refer to the line diagram to determine what other circuits are involved in the cranking cycle. Moving the ignition switch to the "START" position allows battery current to energize relay CR. We see that this relay has two sets of normally closed contacts and one set of normally open contacts. The normally open set does not affect the Cranking Cycle. Since one set closes to complete a circuit to "C" Solenoid which in turn energizes to allow heavy battery current (up to 320 Amps) through the Exciter for cranking, we can assume that these components and circuits are functioning properly since the plant does "turn over".

The other set of normally open contacts of relay CR close to energize the choke heater, ignition coil and fuel valve circuits. We can therefore suspect that the fault is in one of these circuits.

Operation of the fuel valve can be checked by "cracking" a fuel line while the plant is cranked--use caution when doing this. Proper operation of the ignition coil is also easily checked by removing one of the high tension leads and holding it about 1/8" away from the spark plug terminals. A "hot" snappy spark indicates that the coil is in good condition.

By the process of elimination, we have narrowed the trouble to one circuit--the choke heater circuit. With this type of choking device, the choke valve is normally closed and is energized to open as the engine warms up. Conceivably, the valve could "stick" full open; however, failure of the heater would not normally affect starting since it would usually fail in "full choke" position. The position of the choke valve can be observed after removing the air cleaner. Assuming that this is functioning properly, we have to suspect the resistor (R5) that is connected in series with the choke heater.

Since the choke heater operates at 12 Volts, this resistor must function to reduce the 24 Volt energy from the battery to 12 Volts. If it is faulty and allows higher voltage, it could cause the choke valve to move too quickly to the open position, thereby providing too lean a mixture for starting. The Ohm value of the resistor should be checked with the Volt-Ohmmeter.

Although it has taken some time to read through this trouble shooting procedure, actual performance of the steps should take very little time. Running or stopping problems should be just as easy to remedy by using the wiring diagram and applying the same "process of elimination" procedures.

STARTING PROBLEMS

PROBLEM	POSSIBLE CAUSE	APPLIES TO		
		PUSH BUTTON	REMOTE	AUTOMATIC
PLANT WILL NOT CRANK	BATTERY: Check for dead battery, corroded terminals, disconnected leads.	X	X	X
	SWITCH: If remote switch used, try starting with switch on controller. Use jumper to test switches--replace as needed. Check for loose connections.	X	X	X
	CRANKING CONTACTOR C: If contacts do not close when switch is moved to on position, replace relay C.	X	X	X
	CRANKING RESET: If 1TS trips during cranking, it must be reset before plant will crank again. Press reset button--if plant still does not crank, check for open 1TS.	X	X	X
	INSUFFICIENT LOAD: A load of 60 watts or more is needed to start automatic plant. A remote switch can be added to test run these plants--check diagrams.			X
	LOAD RELAY L: Check for dirty or open contacts--replace relay if needed.			X
	CENTER TAP: Three wire automatic plants must have center tap on battery--check for loose leads or missing center tap.			X
	STARTER NOT ENGAGING: Drive pinion may be spinning. Automotive crank plants only.	X	X	X
PLANT CRANKS BUT WILL NOT START	BATTERY: Low charge may be causing insufficient cranking speed--check battery condition.	X	X	X
	IGNITION: Check condition of spark plugs, breaker points for cause of poor spark.	X	X	X
	FUEL: Check fuel supply, fuel filters and lines for clogging. On Diesel models, bleed air out of fuel system.	X	X	X
	CHOKE: Check for inoperative or improperly adjusted choke.	X	X	X
PLANT STARTS RUNNING BUT SHUTS DOWN AFTER ABOUT 45 SECONDS (1TS TRIPS)	LOW OIL PRESSURE: No oil, oil pump faulty, lines clogged. Locate and correct cause.		X	X
	LOP SWITCH: Check for defective LOP switch if no other reason is found for low oil pressure.		X	X
	WS or HT SWITCH: Check for defective water temperature switch on liquid-cooled models or high temperature switch on air-cooled models.		X	X
	RELAY CC: Relay CC may be defective causing shutdown of plant.		X	X
	RELAYS 1CR, 2CR, 3CR: If any of these relays fail, plant could shut down prematurely.		X	
	1TS SWITCH: Check for grounded 1TS switch.		X	

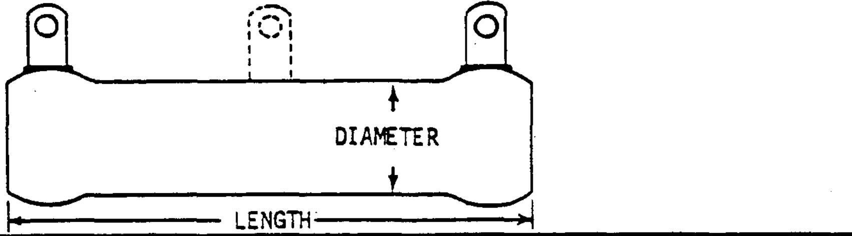
NOTE: The chart above and the chart on the next page are offered as a trouble shooting guide only--all controllers and electric plants will not necessarily have items described. Always locate trouble by tracing the operational sequence in the line portion of the wiring diagram for the particular plant involved. The charts provide some common causes for problems that could occur in normal operation.

OPERATIONAL PROBLEMS

PROBLEM	POSSIBLE CAUSE
BATTERY NOT BEING CHARGED PROPERLY	BATTERY: Check condition of battery--may be sulfated or have cracked cell. Replace as needed. CHARGE SWITCH: If switch left in HAND CRANK position, battery will not be charged. GENERATOR: On plants with automotive cranking, check for faulty DC generator. RESISTOR R2, 1R2: R2 allows low charge rate while 1R2 allows high charge rate. Normal range 12.5 to 14.5 volts. If battery is undercharged, look for excessive resistance in R2 resistor. If overcharging occurs, R2 resistance may be too little REGULATOR RELAY RR: Faulty relay RR could be causing overcharged or undercharged battery--check this after resistor check. RELAY CC: Contacts of relay CC may not be closing to complete battery charging circuit.
NO OUTPUT *(NO EXCITER VOLTAGE-NO AC VOLTAGE)*	BRUSHES - COMMUTATOR: Brushes not seating on commutator or dirty commutator. Also check for loose brush leads. FIELD RESISTOR: Check for open field resistor, broken lead between field resistor and negative brush or between coils. SHUNT FIELD: Remove shunt field lead from field resistor and check for grounded or open field. ARMATURE: Lift brushes off commutator and check for grounded DC armature.
EXCITER VOLTAGE, BUT NO AC VOLTAGE	BRUSHES: AC brushes not riding on collector rings--check for sticking or excessively worn brushes. AC LEADS: Check for open AC lead. AC ARMATURE: Lift AC brushes and check for open circuit in AC armature. AC CIRCUIT: If engine labors while running or jerks while being cranked, check for short in AC leads. If armature gets extremely hot while running, this may indicate a short in the AC armature.
VOLTAGE DROPS EXCESSIVELY UNDER LOAD	SPEED: Check engine speed under load and readjust as needed to correct speed and frequency. Poor compression, faulty ignition or any other condition causing poor performance of engine will show up in reduced output. AUXILIARY FIELD: Check for reversed auxiliary field--F1 must be positive on negative ground plants. Remove F1 terminal and check resistance across F1 and F2 field leads for shorted or open field.
EXCESSIVE ARCING OF BRUSHES	WRONG BRUSHES: Order brushes only per specifications--carbon content varies considerably between plants. BRUSH TENSION: Incorrect tension caused by wrong springs, excessively or unevenly worn brushes. Replace brushes and springs.
PLANT RUNS-ON AFTER SHUT DOWN	ENGINE DIESELING: Shut off all fuel or air to stop--install anti-dieseling devices to remedy. RESIDUAL LOAD: On automatic plants, a small load may be keeping the plant operating past expected shut down--locate and eliminate.

COMMON RESISTORS

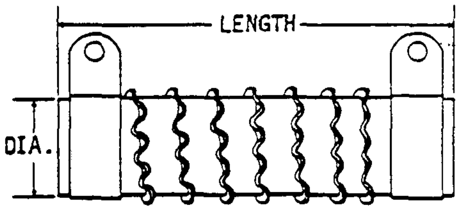
FIXED RESISTORS



Watts	Ohms	Length	Diameter	Part No.
5	10.	1"	5/16"	246126
	30.	"	"	243970
	50.	"	"	243971
	75.	"	"	246181
	100.	"	"	243584
	200.	"	"	283126
	250.	"	"	265324
	270.	"	"	243617
	750.	"	"	265968
	1000.	"	"	X-471-4
	1250.	"	"	243354
	2000.	"	"	243976
	3000.	"	"	X-471-1
	4000.	"	"	243611
	9250.	"	"	X-471-2
	13000.	"	"	X-471-3
	33000.	"	"	283279
10	2.	1-3/4"	5/16"	X-472-1
	3.	"	"	243307
	4.	"	"	283123
	4.5	"	"	X-472-3
	5.	"	"	243046
	7.	"	"	265325
	8.	"	"	X-472-4
	10.	"	"	265941
	15.	"	"	265963
	20.	"	"	X-472-2
	25.	"	"	243126
	30.	"	"	156840
	50.	"	"	243439
	125.	"	"	243614
	300.	"	"	243127
	400.	"	"	231095
	5000.	"	"	243358
	7000.	"	"	243021
	8000.	"	"	243380
	39000.	"	"	283280
20	1.25	2"	7/16"	232136
	2.5	"	"	243489
	4.	"	"	X-474-3
	5.	"	"	223028
	10.	"	"	243564
	15.	"	"	X-474-4
	20.	"	"	266360
	30.	"	"	243585
	40.	"	"	X-474-6
	80.	"	"	X-474-7
	125.	"	"	X-474-5
	200.	"	"	243024
	500.	"	"	X-474-1
	550.	"	"	X-474-2
	1000.	"	"	283184
	2500.	"	"	161734
25	10.	2"	5/8"	243790
	20.	"	"	265818
30	2.5	3"	3/4"	243899
	7.5	"	"	243797
	10.	"	"	243891
	10.*	"	"	X-475-3
	15.	"	"	243890
	25.	"	"	X-475-1
	30.	"	"	X-475-2
40	7.5	3-1/2"	3/4"	266359
	10.	"	"	265326
	20.	"	"	X-476-1
	75.	"	"	265964
	1000.	"	"	243534
50	2.5	4-1/2"	5/8"	243871
	4.	"	"	X-478-5
	5.	"	"	243849
	7.5	"	"	X-478-4
	10.	"	"	243898
	15.	"	"	X-478-6
	20.	"	"	X-478-3
	30.	"	"	268021
	40.	"	"	X-478-1
	60.	"	"	X-478-2
	300.	"	"	X-478-7

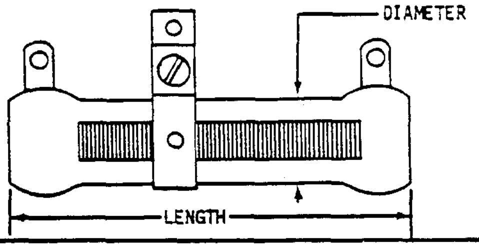
**Center tapped*

FIXED-RIBBON TYPE



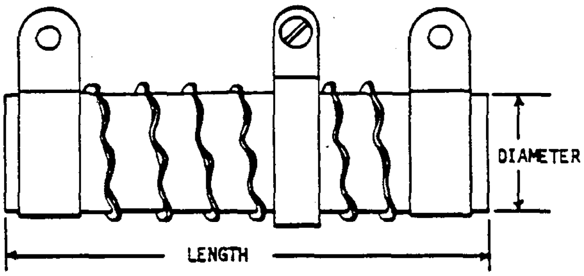
Watts	Ohms	Length	Diameter	Part No.
125	1.5	4"	1"	245291
	2.	"	"	245421
	2.5	"	"	245442
	3.5	"	"	245457
	4.	"	"	245519
	5.	"	"	X-566-2
	6.	"	"	X-566-1

VARIABLE RESISTORS



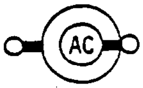
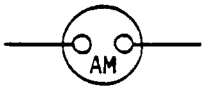
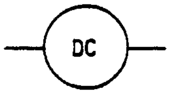
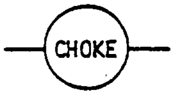
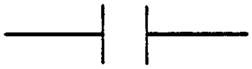
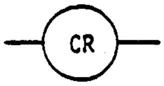
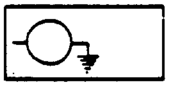
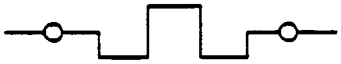
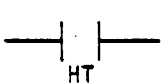
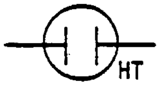
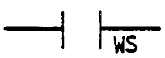
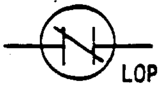
Watts	Ohms	Length	Diameter	Part No.
10	7.5	1-3/4"	5/16"	243260
	10.	"	"	X-473-2
	20.	"	"	233060
	30.	"	"	X-473-1
	100.	"	"	X-473-3
	2500.	"	"	X-473-4
25	.25	2"	5/8"	242819
	.35	"	"	242919
	1.	2"	-	242213
	7.5	2"	9/16"	243144
	10.	2"	-	242289
	45.	2"	5/8"	242577
	60.	"	"	223017
	75.	"	"	223120
	160.	"	"	242642
	200.	2"	9/16"	243125
	500.	2"	5/8"	287051
	1500.	"	"	283071
40	2.5	3-1/2"	3/4"	265241
	4.	"	"	X-477-1
50	.5	4-1/2"	5/8"	X-479-2
	5.	"	"	233055
	10.	"	"	X-479-1

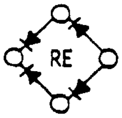
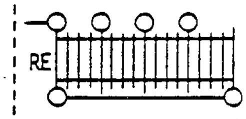
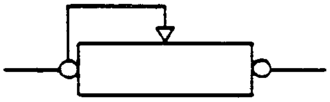
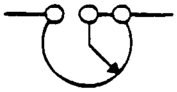
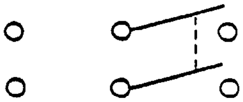
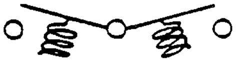
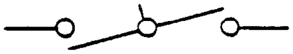
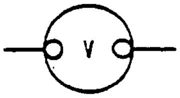
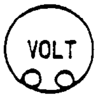
VARIABLE-RIBBON TYPE



Watts	Ohms	Length	Diameter	Part No.
40	0.5	2-1/2"	3/4"	242454
	1.0	"	"	252180
	1.5	"	"	242392
	2.0	"	"	243902
	2.5	"	"	246610
	3.0	"	"	242698
	4.0	"	"	242088
125	1.5	4"	1"	X-694-1
	6.0	"	"	X-694-2

KOHLER WIRING DIAGRAM SYMBOLS

ITEM	LINE SYMBOL	SCHEMATIC SYMBOL
ALTERNATOR		
AMMETER		
ARMATURE, EXCITER		
BREAKER, CIRCUIT		
BATTERY		
CHOKE		
CONDENSER		
CONTACTS - NORMALLY CLOSED		
CONTACTS - NORMALLY OPEN		
COIL		
COIL, HEAT		
CUTOUT - HIGH TEMPERATURE		
CUTOUT - WATER TEMP. SWITCH		
CUTOUT - LOW OIL PRESSURE		
FIELD		
FUSE		
GROUND		
MAGNETO		

ITEM	LINE SYMBOL	SCHEMATIC SYMBOL
RECTIFIER, BLOCKING		
RECTIFIER, FULL WAVE		
RESISTOR, FIXED		
RESISTOR, VARIABLE (ADJUSTABLE).		
RHEOSTAT		
SWITCH - DOUBLE POLE, DOUBLE THROW		
SWITCH - DOUBLE POLE, SINGLE THROW		
SWITCH, SINGLE POLE, SINGLE THROW		
SWITCH, MOMENTARY CONTACT		
SWITCH, PUSH BUTTON - NORMALLY CLOSED		
SWITCH, PUSH BUTTON - NORMALLY OPEN		
SWITCH, SNAP		
TERMINAL		
TRANSFORMER		
VOLTMETER		

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KOHLER
KOHLER CO.
Kohler, Wis. 53044

Technical Publications
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T I Series No. EL-9

TECHNICAL INFORMATION

KOHLER
GENERATOR SETS

PARALLEL OPERATION

KOHLER CO.
Kohler, Wis. 53044

ES-914

There are a number of variables which affect proper load division and successful paralleling. Plants to be paralleled must have the following common factors:

1. Same frequency
2. Same voltage
3. Same number of phases
4. Same phase rotation
5. Same speed regulation characteristics
6. Same voltage regulation characteristics

NOTE: *Rotating armature plants cannot be successfuly paralleled because they cannot remain locked in step due to voltage regulation characteristics.*

To achieve successful paralleling, special instruments and control devices must be used. These include synchronizing lights, load transfer switches or circuit breakers, frequency and droop adjustments on governor, voltage adjustment provisions, and accurate meters for measuring results of adjustments. The necessary meters are AC wattmeter, voltmeter and ammeter. The function of these devices and instruments are discussed where applicable in the following--refer to the glossary at the back of this manual for the description of any terms which may not be familiar to you.

GOVERNOR REQUIREMENTS: Isochronous and vacuum compensated governors cannot be used for parallel operation unless used in conjunction with automatic paralleling equipment--contact Kohler Co. for specific details before using a generator set with either of these types of governors for parallel operation. Isochronous governors tend to maintain a relatively constant engine speed regardless of changing load conditions which is undesirable in normal paralleling applications. Vacuum compensated governors do not droop in uniform manner. The governors used must allow a certain amount of speed droop to prevent hunting when plants are paralleled. Governors must be adjusted to allow the same speed droop before the plants can be paralleled. Speed droop from no load to full load should be about 2 cycles on 1800 RPM, 60 cycle plants although more droop is needed in some applications. If governor speed droop is not equal, proper division of active load cannot be achieved since the plant having less speed droop will carry more than its share of the load. Correct division of active power is best accomplished using wattmeters to read actual KW output of the plants. This method is more accurate than using ammeters. When adjusted properly, each plant will carry its proportionate share of the load regardless of changing load conditions. With two plants of identical KW capacity, the active load should be divided equally between the two. With plants of unequal capacity, the load should be divided proportionately according to overall capacity of both plants. For example, with a 50 KW plant and 100 KW plant on a 120 KW load, the smaller plant should carry 33-1/3% (150 ÷ 50 = 33-1/3) or about 40 KW and the larger plant the remainder or, in this case, 80 KW.

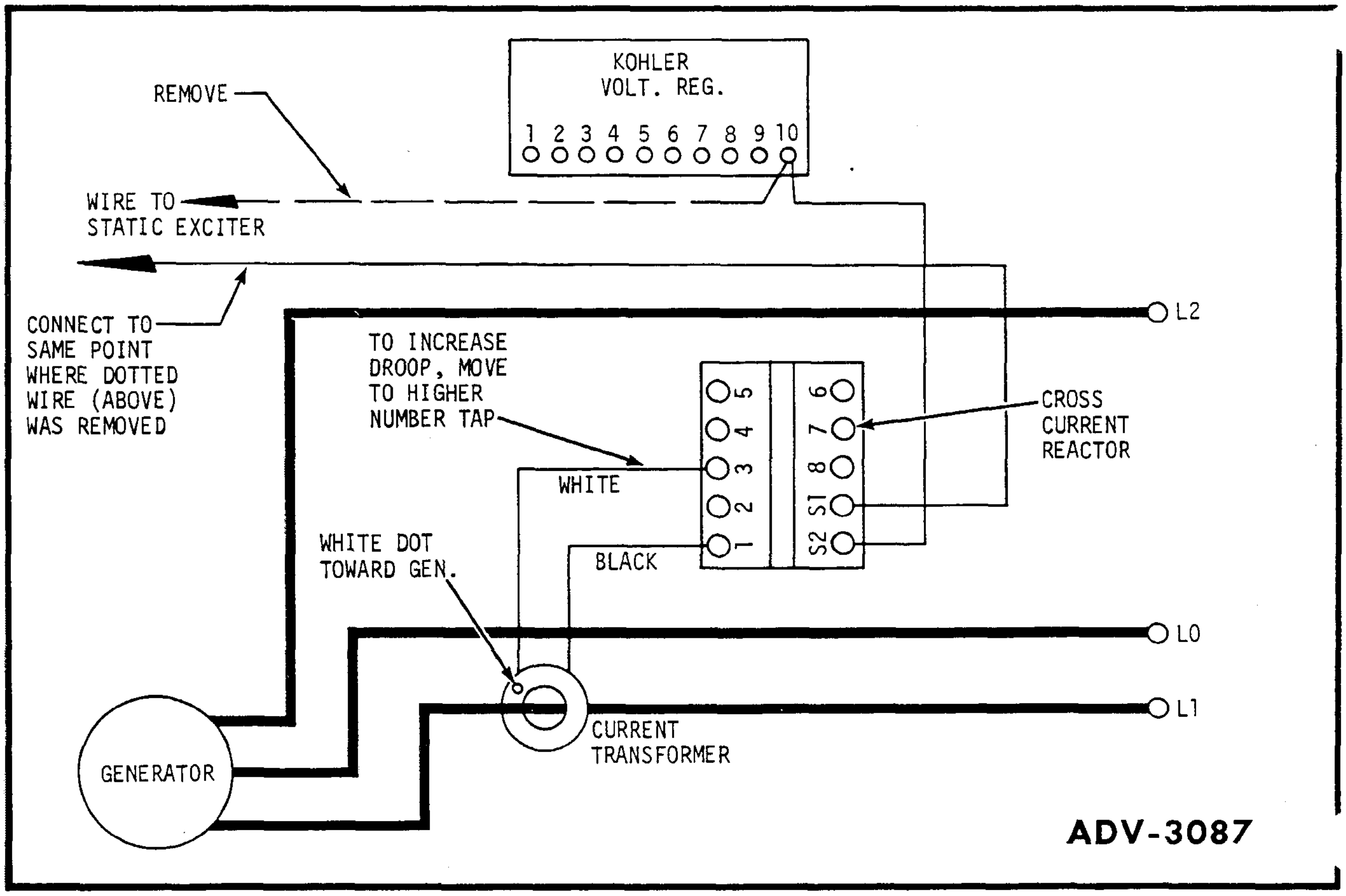
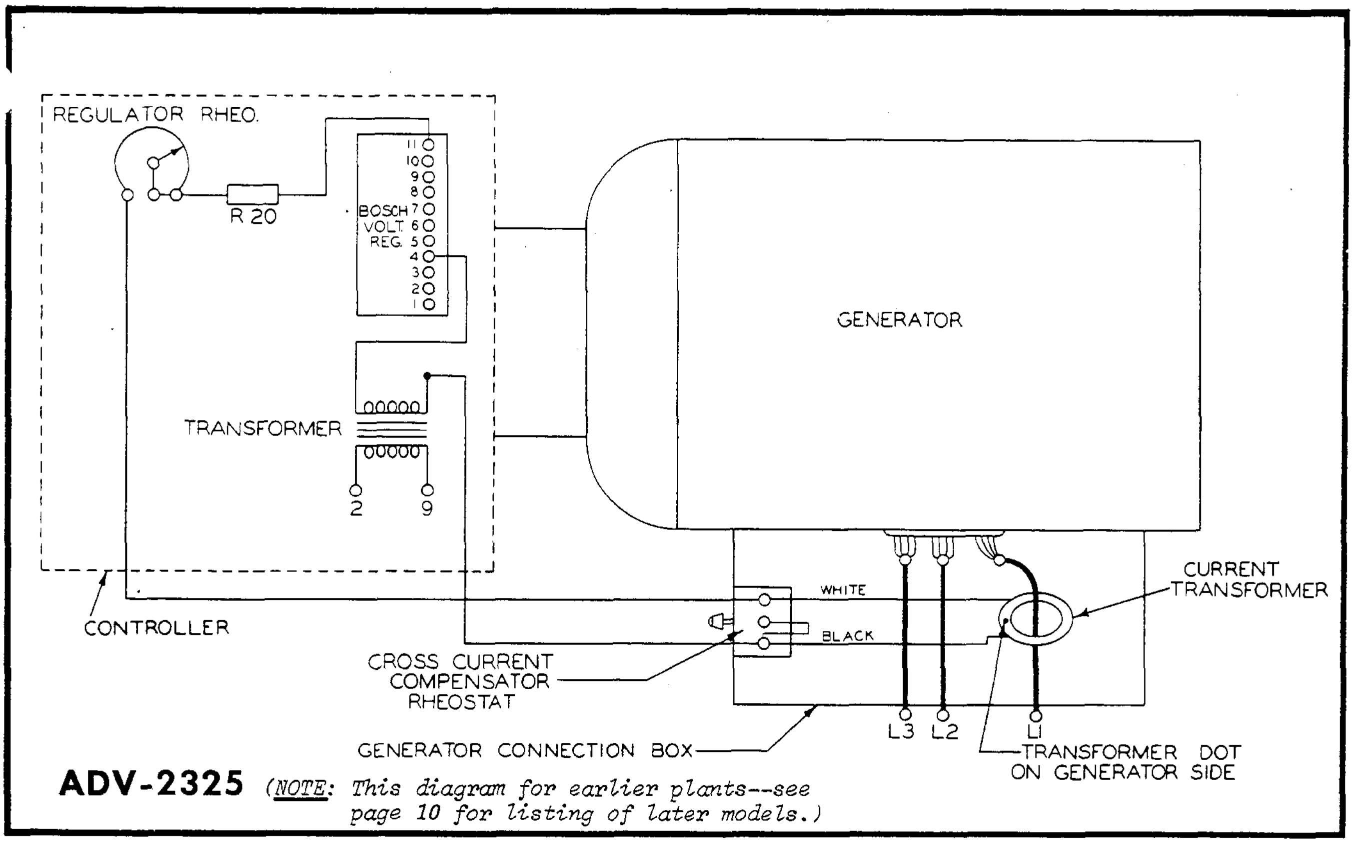


FIGURE 1 -- REACTIVE DROOP COMPENSATOR DIAGRAM - SINGLE PHASE PLANT



ADV-2325 *(NOTE: This diagram for earlier plants--see page 10 for listing of later models.)*

FIGURE 2 -- REACTIVE DROOP COMPENSATOR DIAGRAM - THREE PHASE PLANT

INTERNAL VOLTAGE: If field excitation or internal voltage differs on plants in parallel, the plant with the higher internal voltage will furnish reactive power to the plant with lower internal voltage in amounts sufficient to make up the difference. Reactive power does no useful work but must be divided proportionately between the plants since it does affect capacity of the plants. When internal voltage is unequal, cross currents flow between the generators to limit capacity of the plant having the highest internal voltage. When plants of identical size and with same method of excitation are paralleled, internal voltage should be the same; however, with plants of different size and excitation, some means of compensating for differing internal voltages must be provided. On single phase plants, adjustment is provided by changing taps on a phase shifting transformer. On three phase plants, a reactive droop transformer and rheostat are used.

After actual KW load has been divided proportionately, the reactive load should also be balanced between plants--results are indicated by reading current flow in an output lead of the generator with an ammeter.

REACTIVE DROOP: While reactive load can be balanced equally between parallel plants as explained in the foregoing, it does not, unfortunately, remain constant with changing load. In other words, reactive power droops in much the same manner as actual power. This is attributed to regulation characteristic differences between the plants--the plant which has the more precise regulation will allow the smallest reactive droop but will also carry the highest share of reactive power, which thus reduces its active load carrying capabilities. To correct this, a reactive droop compensation circuit is utilized to cause both plants to divide, proportionately, the reactive droop as reactive power changes. Reactive droop of four percent of rated voltage is considered satisfactory in most applications. Addition of the reactive droop compensation adversely affects overall regulation of both plants however this effect is offset by improved output. If either plant is to be operated alone, a switch can be added to make the reactive droop compensator circuit inoperative to improve voltage regulation characteristics when plants are not in parallel.

Refer to page 10 for listing of Reactive Droop Compensators.

SYNCHRONIZATION: As discussed earlier, the wave form of the incoming plant must be synchronized to be in step timewise or in the same sequence as that of the operating plant. Synchronizing lights are used to indicate when plants are in phase and synchronization is achieved by adjusting governed speed or frequency of the incoming plant.

When plants are out of phase, voltage will be highest and the synchronizing lights will be brightest and will alternate from bright to dim very rapidly. As governed speed is adjusted to bring the wave form closer together, voltage and brightness of the lights decrease. When the lights are darkest and alternate from bright to dim slowly, the wave forms are closest together indicating that the incoming plant is ready to be paralleled to the operating plants. On three phase plants, an additional set of synchronizing lights is often used to achieve correct phase sequence.

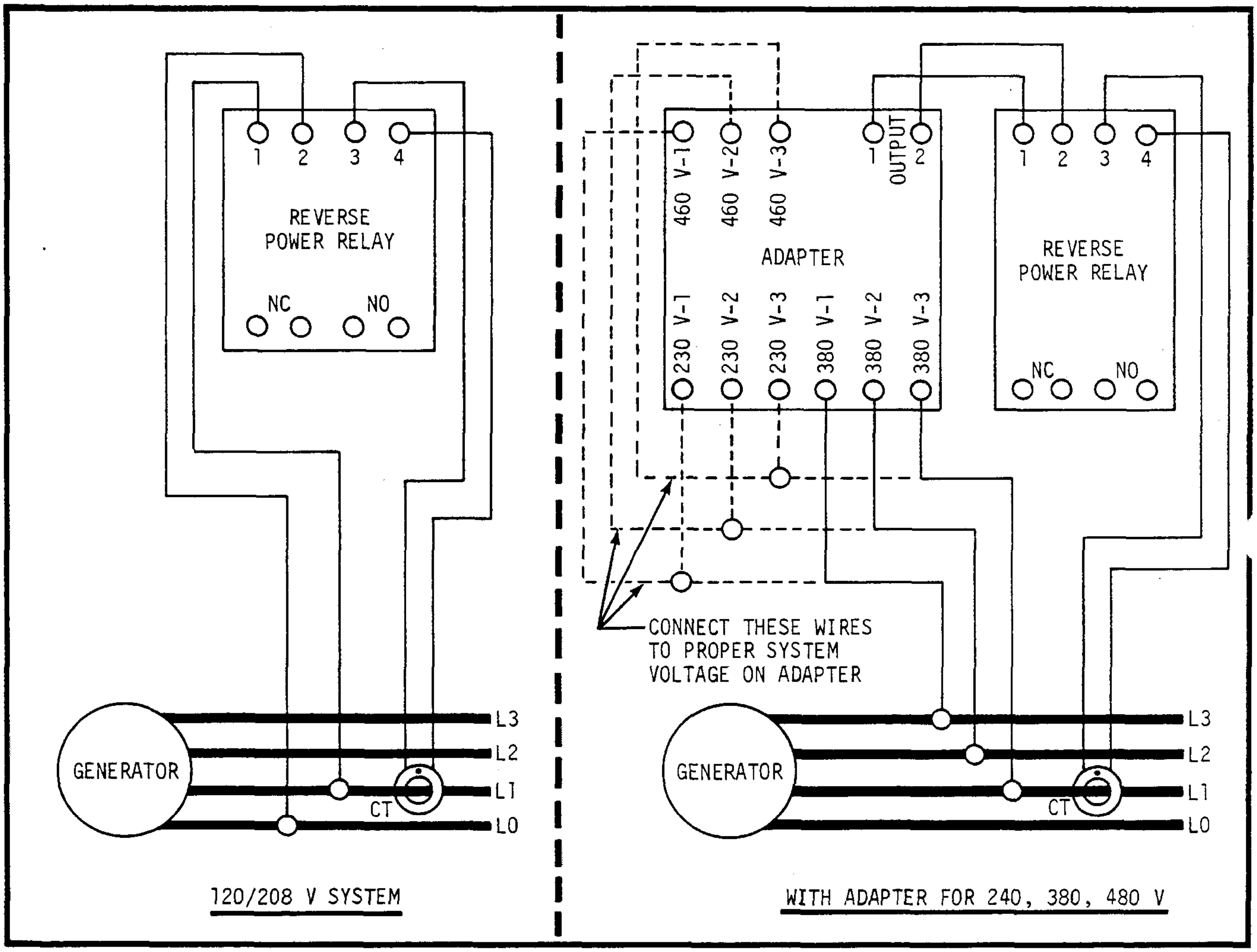


FIGURE 3 -- REVERSE POWER RELAY PROTECTIVE CIRCUITS

The phase rotation of parallel plants must be the same. A convenient method of checking this is to connect an induction motor (of correct phase) to each plant individually. If the motor rotates in the same direction on all plants, this indicates that the phase rotation is the same.

The synchronizing and paralleling procedure may vary somewhat with different types of plants. The procedures are detailed later in this manual.

PROTECTIVE DEVICES: A reverse power relay senses the direction of power flow. One is connected in each generator circuit as a protective device. If any plant in the system has a malfunction causing current to flow into the generator, the reverse power relay will sense the reverse power and disconnect the plant from the system. If reverse power relays are not used, plants still running will drive the plant that has stopped as a motor, causing extensive damage to this plant.

PARALLELING PROCEDURE

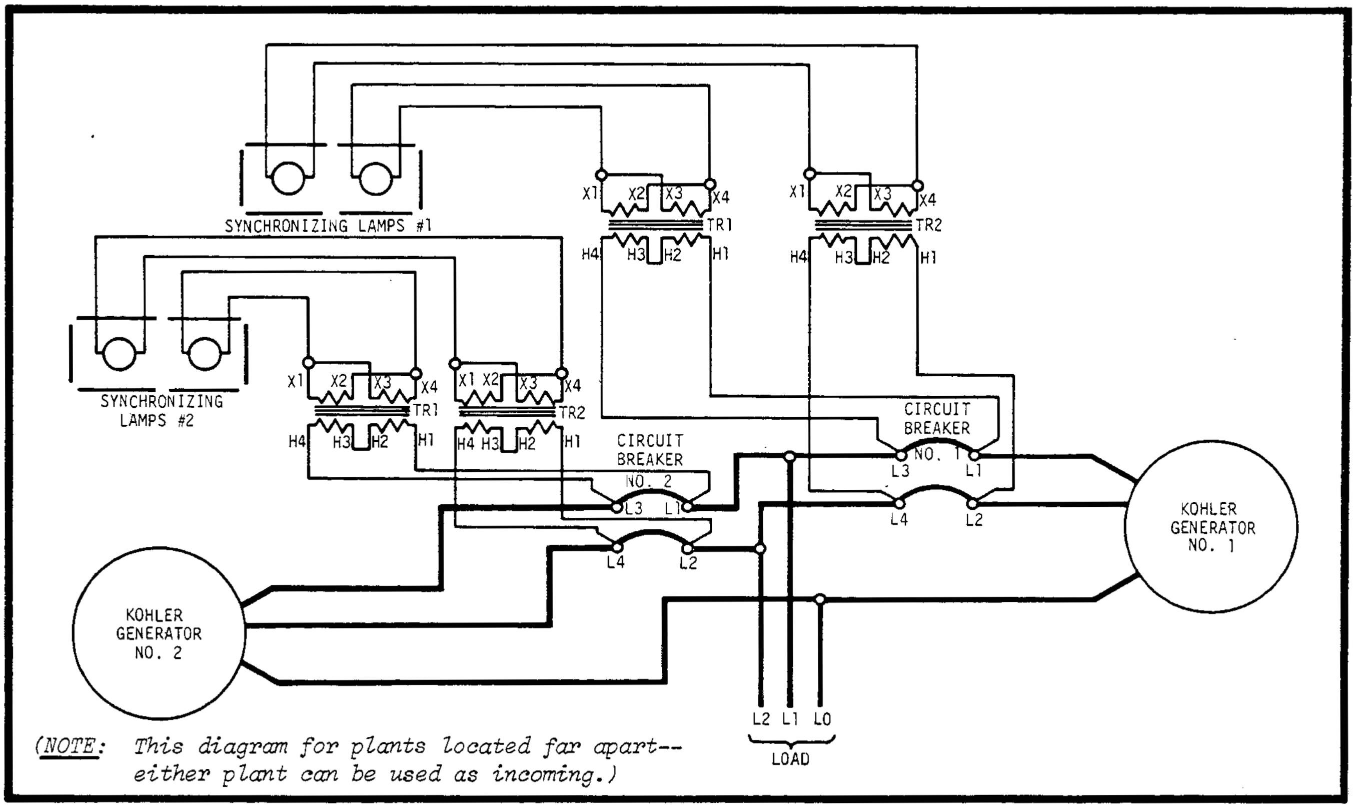
The following procedure can be used providing all paralleling requirements described earlier have been met and that plants are properly equipped for parallel operation. The following preliminary steps pertain to manual and automatic synchronized plants.

PRELIMINARY STEPS

STEP 1: Start unit number 1, close line circuit breaker connecting it to load then check and record voltage and RPM at 1/4, 1/2, 3/4 and full load. Open line circuit breaker and shut down this plant.

STEP 2: Start unit number 2 and repeat procedure called for in step one on this plant.

STEP 3: Compare readings and adjust each plant individually so that speed is within 3 RPM and voltage within one volt under each test load level.



(NOTE: *This diagram for plants located far apart-- either plant can be used as incoming.)*

FIGURE 4 -- PARALLELING WIRING DIAGRAM - SINGLE PHASE PLANTS

STEP 4: Check droop compensation on each plant individually as follows. With plant operating at corrected speed and voltage, apply a lagging power factor load (unity or resistance loads cannot be used for this check). First short out all resistance of the rheostat and record voltage then adjust rheostat with all resistance in and record voltage. Voltage obtained with all resistance shorted out should be slightly greater than with all resistance in--if lower, shut down the plant and reverse the direction of the generator load thru the cross current transformer or reverse transformer leads to correct droop compensation. With full load 0.8 power factor, a droop of 3-5% should be adequate for paralleling.

PARALLELING PROCEDURE (MANUAL WITH LIGHTS)

After preliminary tests and adjustments have been made, they will not have to be repeated each time the plants are to be paralleled--repeat only when adjustments are changed. It is necessary to synchronize the plants before each parallel operation. The following covers manual synchronization using synchronizing lights.

SYNCHRONIZATION STEPS

STEP 1: Make sure line circuit breakers or main switches are open then start both plants.

STEP 2: Put synchronizing lights on then close the line circuit breaker on one plant only.

STEP 3: Observe synchronizing lights then adjust speed on the plant with circuit breaker off until the lamps fluctuate bright-dark slowly (about one flash every 2 seconds).

STEP 4: At the instant the synchronizing lights are darkest, close the line circuit breaker on the incoming plant--immediately after paralleling, return the governor speed of this plant to its initial setting so that it will carry its share of the load.

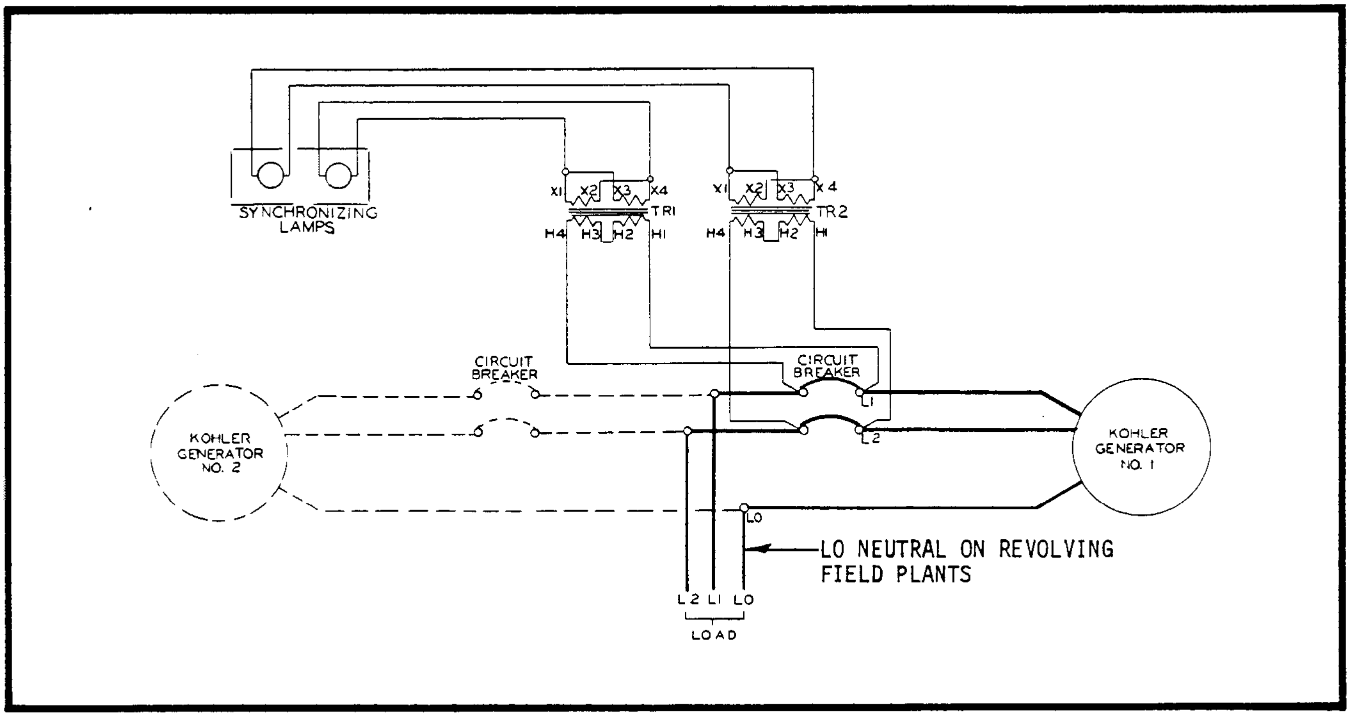


FIGURE 5 -- PARALLELING DIAGRAM - SINGLE PHASE 120/240 V PLANTS (283579)

ADJUSTMENT PROCEDURE

Synchronization can be accomplished automatically with properly equipped plants; however, the following checks and adjustments apply to both manually and automatically synchronized plants.

STEP 1: Run plants in parallel at no load for about five minutes. After this period of time, observe ammeters on paralleling panel. If an excessive circulating current (above 10% of rated current) is indicated, readjust voltage regulator rheostat on three phase plants or single phase plants. Adjust until both ammeters are at lowest reading--this should be at the same value on equal plants or proportional values with plants of unequal size.

STEP 2: Apply load to both plants and check active load division by observing wattmeters. The only way to divide load proportionately is by increasing governor throttle control. After two loads are correctly divided as indicated by the wattmeters, frequency can be checked on either frequency meter. If the frequency is too high, it will be necessary to readjust both the governor controls to lower speed. Conversely, if the combined speed is too low, increasing the governor controls on both plants will increase the frequency. When raising or lowering the frequency, care must be taken to readjust the load divisions so that the wattmeter readings will again be equal or proportional to the size of the generators if the sets are not of the same size. Do not attempt to divide load by changing voltage regulation.

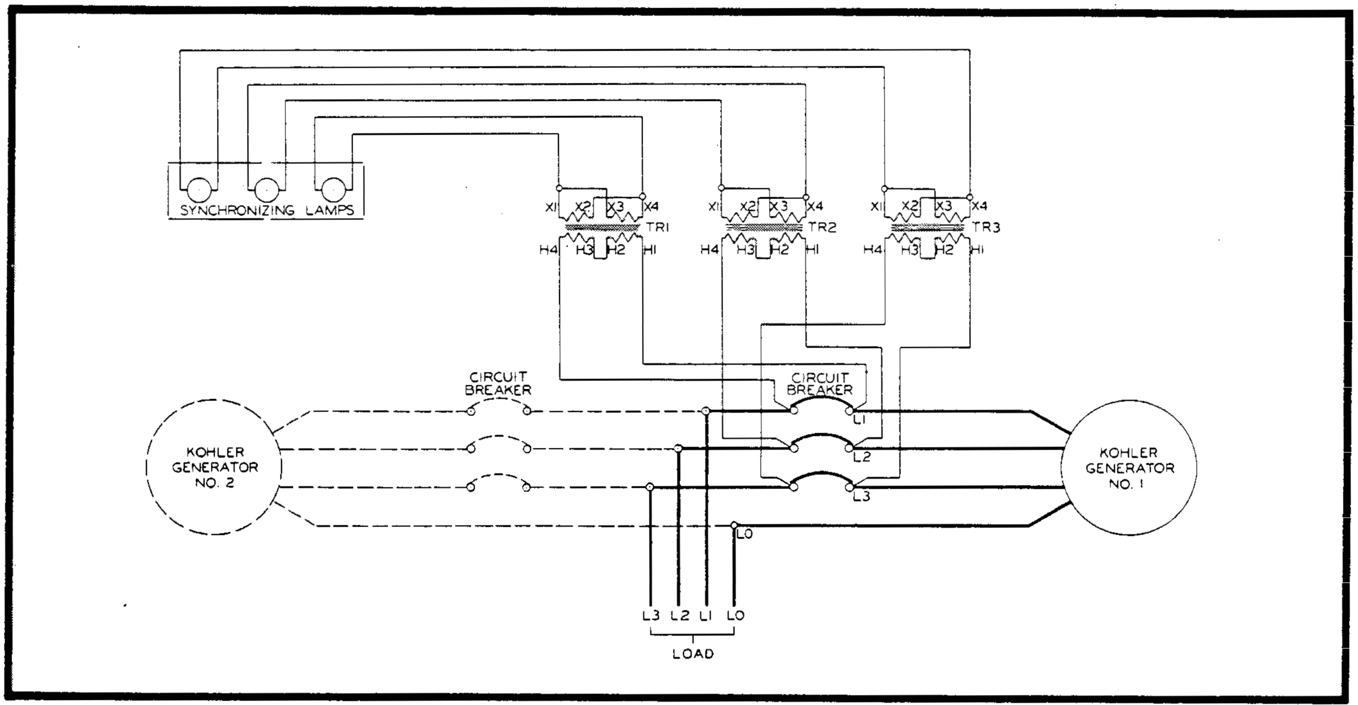


FIGURE 6 -- PARALLELING DIAGRAM - THREE PHASE, 4 WIRE PLANT (283536)

Paralleling Operational Factors: The following points are re-emphasized here to stress their importance to successful operation of plants in parallel.

1. Voltage adjustments must not be made after plants are initially adjusted for equal voltage.
2. Voltage must droop on power factor loads. A little compounding voltage is acceptable on unity loads.
3. Wattmeter unbalance is due only to differences in engine speeds.
4. The cross current rheostat is used only to balance current on power factor loads.

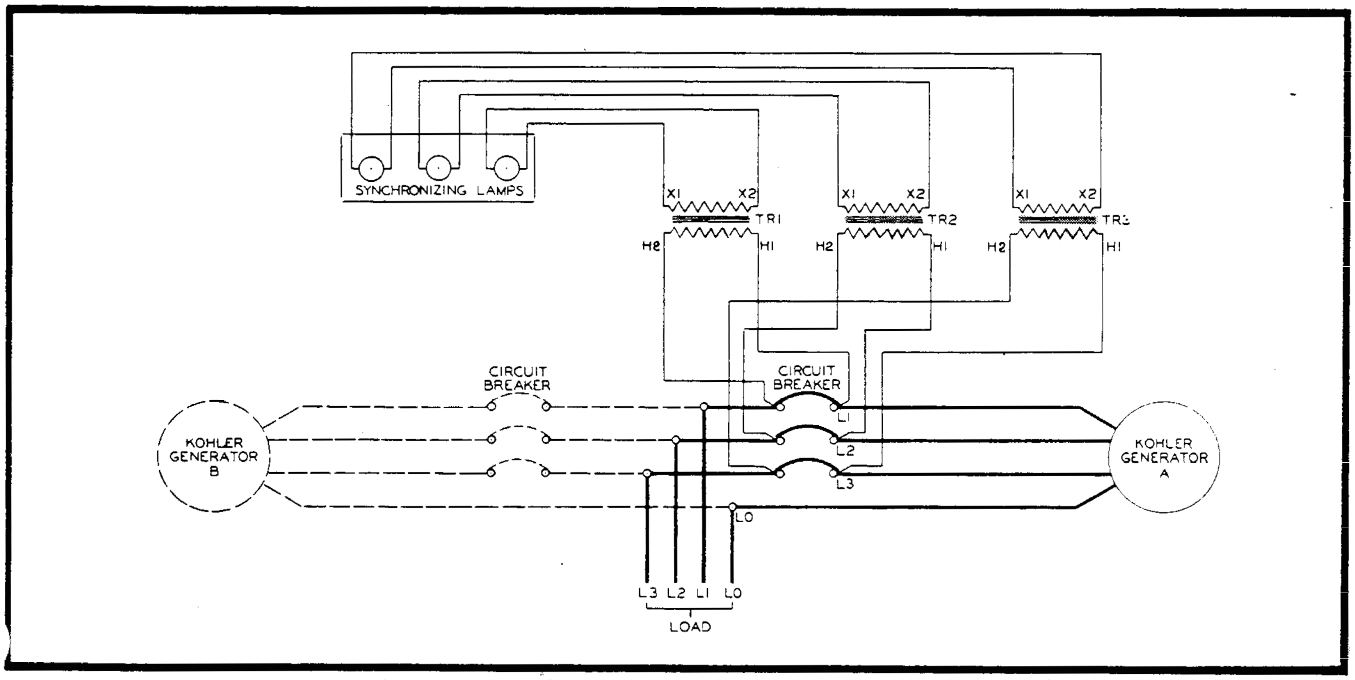


FIGURE 7 -- PARALLELING DIAGRAM - THREE PHASE 380 OR 480 V PLANT (283592)

REACTIVE DROOP COMPENSATORS

(With Synchronizing Lamp)

PLANT MODEL (KW)	EXCITER TYPE	REGULATOR TYPE	PHASE AND VOLTAGE	ASSEMBLY NUMBER	WIRING * DIAGRAM
10.0	Rotating	Kohler	Single Phase - 240 V	282516	268669 & ADV-2552
10.0	Rotating (Rev. Field)	Kohler	3 Phase - 120/208, 240, 480 V (240 V Sensing)	282515	268669 & ADV-2552
15.0	Rotating	Kohler	Single Phase - 240 V	282516	268669 & ADV-2552
15.0	Rotating (Rev. Field)	Kohler	3 Phase - 120/208, 240, 480 V	282515	ADV-2488 & ADV-2551
30.0	Rotating	Kohler	Single Phase - 240 V	282516	ADV-2488 & ADV-2551
30.0	Rotating	Basler	Single Phase - 240 V	282514	ADV-2485
30.0	Static	Kohler	Single Phase	282596	ADV-3087
30.0	Rotating	Kohler	3 Phase - 120/208, 240, 480 V	282515	ADV-3087
30.0	Rotating	Basler	3 Phase - 120/208, 240, 480 V (240 V Sensing)	282512	ADV-2373
30.0	Static	Kohler	3 Phase - 120/208, 240, 480 V	282549	ADV-2550
45.0	Rotating	Basler	Single Phase	282514	ADV-2550
45.0	Rotating	Basler	3 Phase, 120/208, 240, 480 V	282513	ADV-2373
45.0	Static	Kohler	3 Phase, 120/208, 240, 480 V	282550	ADV-2550
55.0	Rotating	Basler	3 Phase - 120/208, 240, 480 V	282513	ADV-2550
55.0	Static	Kohler	3 Phase - 120/208, 240, 480 V	282550	ADV-2550
70.0	Rotating	Basler	3 Phase - 120/208, 240, 480 V	282521	ADV-2373 & ADV-2550
70.0	Static	Kohler	3 Phase - 120/208, 240, 480 V (240 V Sensing)	282521	ADV-2373 & ADV-2550
85.0	Rotating	Basler	3 Phase - 120/208, 240, 480 V	282521	ADV-2373 & ADV-2550
85.0	Static	Kohler	3 Phase - 120/208, 240, 480 V	282521	ADV-2373 & ADV-2550
110.0	Static	Kohler	3 Phase - 120/208, 240, 480 V	282522	ADV-2550 & ADV-2551
115.0	Rotating	Bosch	3 Phase - 120/208, 240, 480 V	282450	ADV-2325
115.0	Rotating	Kohler	3 Phase - 120/208, 240, 480 V	282522	ADV-2550 & ADV-2551
150.0	Rotating	Bosch	3 Phase - 120/208, 240, 480 V	282450	ADV-2550 & ADV-2551
150.0	Rotating	Kohler	3 Phase - 120/208, 240, 480 V	282523	ADV-2550 & ADV-2551
150.0	Static	Kohler	3 Phase - 120/208, 240, 480 V	282523	ADV-2550 & ADV-2551
175.0	Rotating	Bosch	3 Phase - 120/208, 240, 480 V	282509	ADV-2325
175.0	Rotating	Kohler	3 Phase - 120/208, 240, 480 V	282523	ADV-2325
175.0	Static	Kohler	3 Phase - 120/208, 240, 480 V	282523	ADV-2325
200.0	Static	Kohler	3 Phase - 120/208, 240, 480 V	282523	ADV-2325
230.0	Static	Kohler	3 Phase - 120/208, 240, 480, 600 V	282523	ADV-2325

**Wiring Diagrams ADV-3087 and ADV-2325 on pages 4 & 5--other diagrams on following pages.*

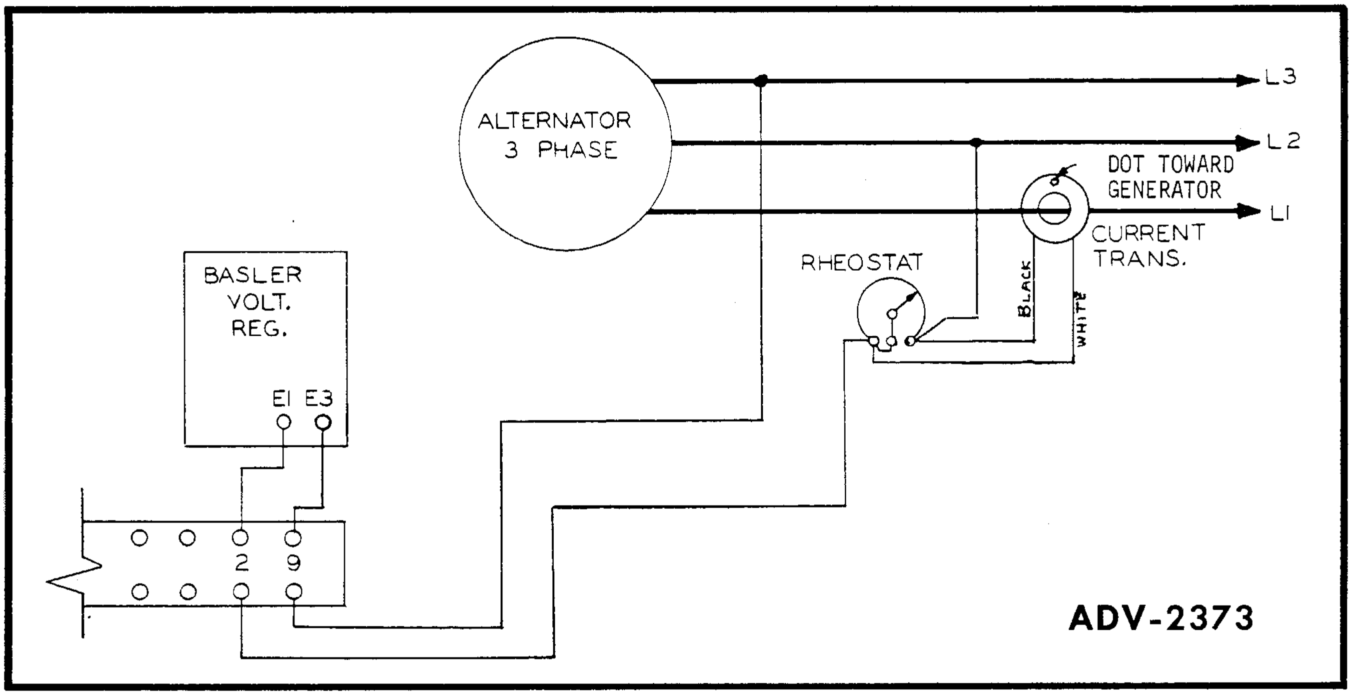


FIGURE 8 -- COMPENSATOR DIAGRAM - ROTATING EXCITER, 3 PHASE WITH BASLER REGULATOR

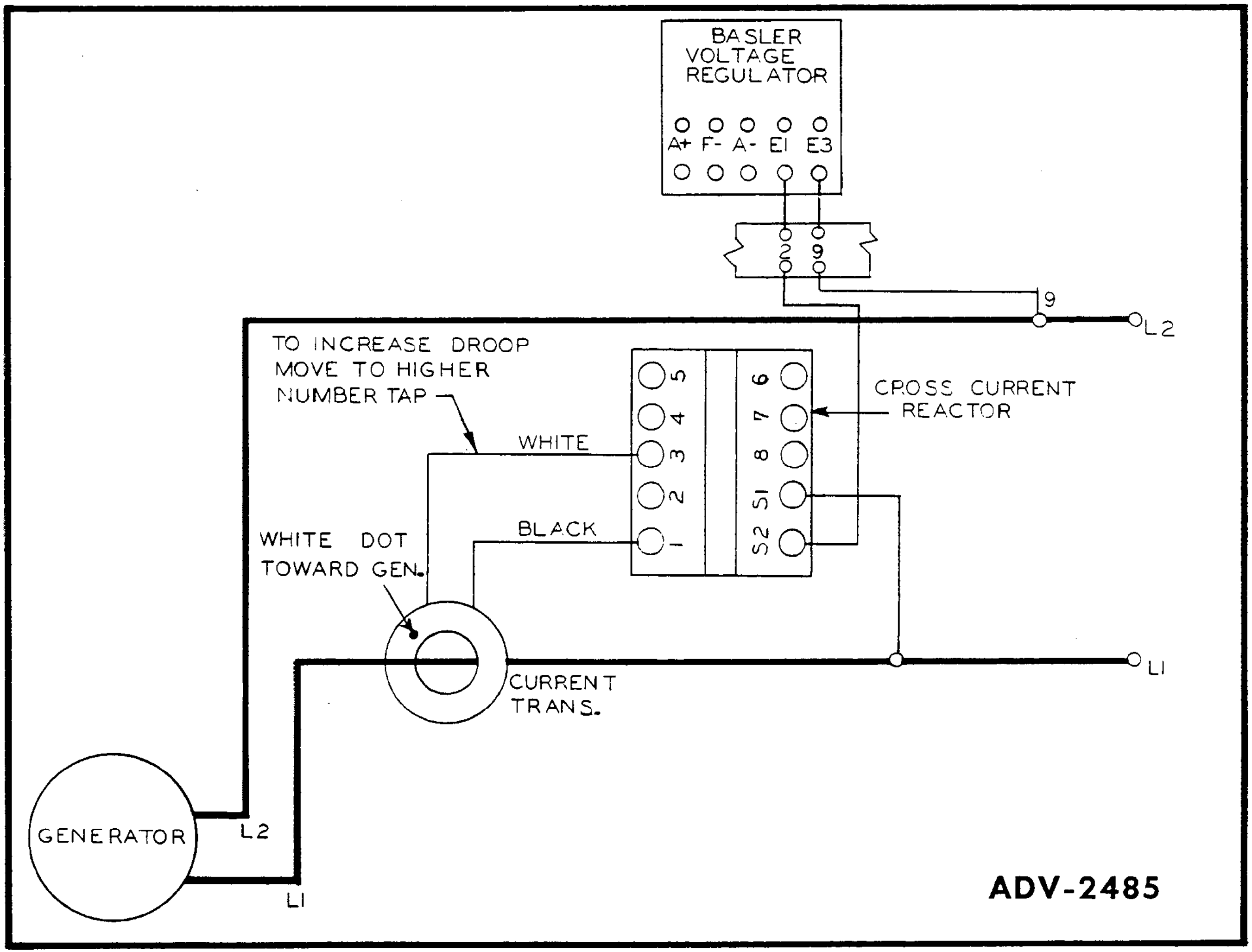


FIGURE 9 -- COMPENSATOR DIAGRAM - ROTATING EXCITER, SINGLE PHASE WITH BASLER REGULATOR

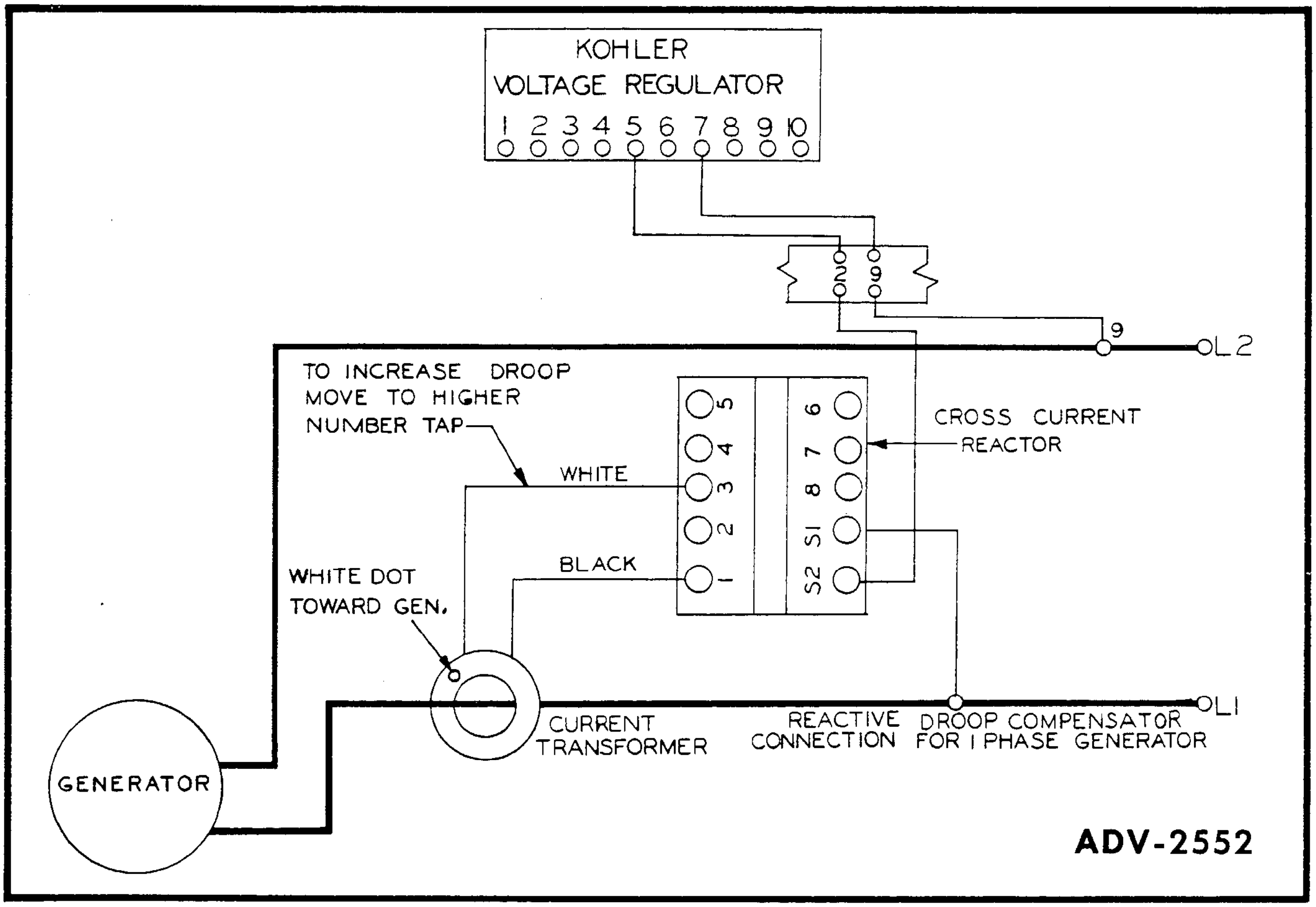


FIGURE 10 -- COMPENSATOR DIAGRAM - ROTATING EXCITER, SINGLE PHASE WITH KOHLER REGULATOR

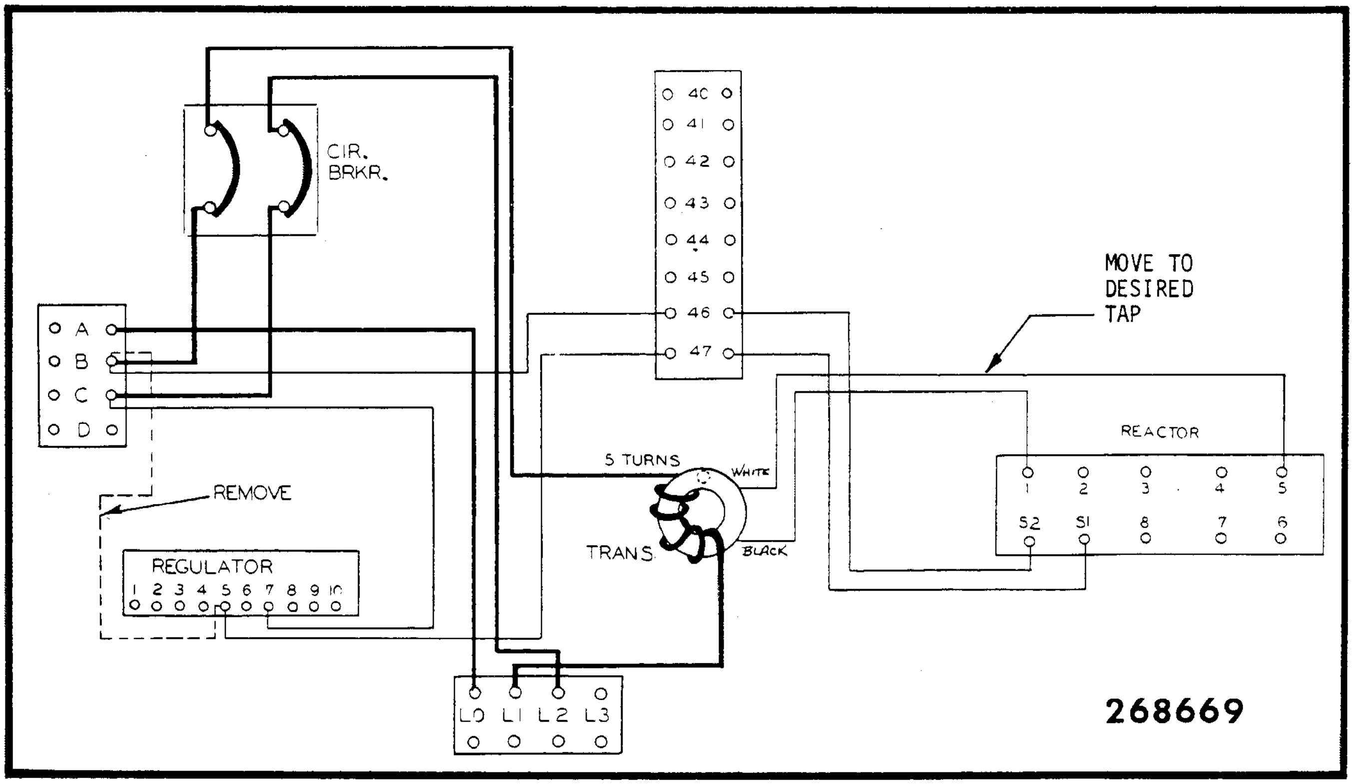


FIGURE 11 -- COMPENSATOR DIAGRAM - ROTATING EXCITER, SINGLE PHASE WITH KOHLER REGULATOR

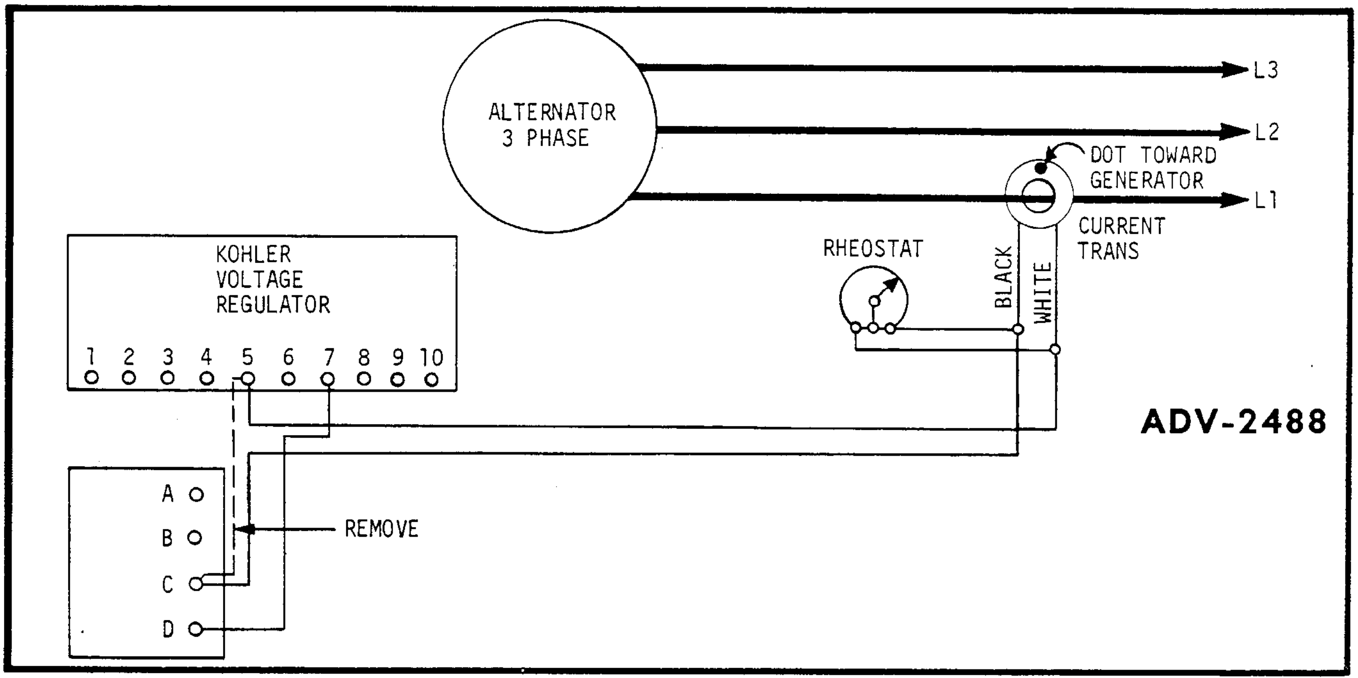


FIGURE 12 -- COMPENSATOR DIAGRAM - REVOLVING FIELD, ROTATING EXCITER, 3 PHASE, KOHLER REGULATOR

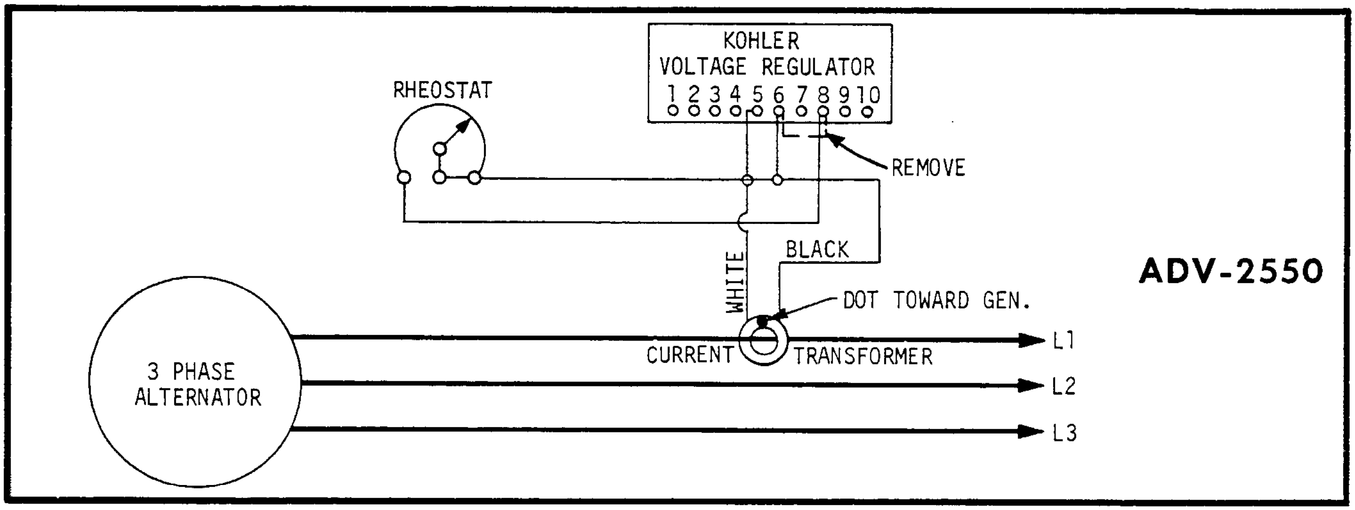


FIGURE 13 -- COMPENSATOR DIAGRAM - STATIC EXCITER, 3 PHASE WITH KOHLER REGULATOR

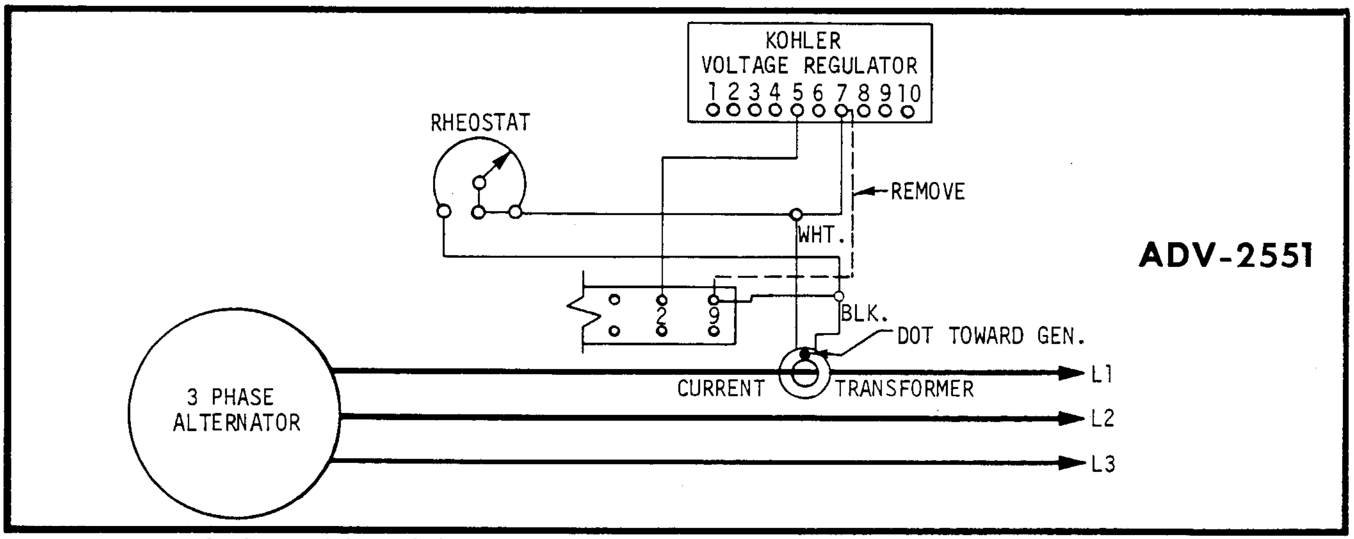


FIGURE 14 -- COMPENSATOR DIAGRAM - ROTATING EXCITER, 3 PHASE WITH KOHLER REGULATOR

GLOSSARY

TERMS RELATING TO PARALLELING

AMMETER: Instrument for reading reactive power output of plants in parallel.

CIRCUIT BREAKER: Switch used to connect plant with another plant to a common load after synchronization.

COMPENSATOR: Device used to equalize power in proportion to capacity of each plant operating in parallel. Refer to reactive droop and cross-current compensation.

CROSS-CURRENT: When internal voltage is unequal between plants in parallel, cross-currents flow between the generators which adversely affects capacity. To counteract this, some means of adjusting internal voltage must be provided on parallel plants.

COMPOUNDING: In paralleling, build up of voltage. With unity power factor loads, a certain amount of compounding is acceptable but with lagging power factor loads, voltage must droop.

DIVISION - KW LOAD: Each plant in parallel must carry its share of the KW or active load in proportion to its rated capacity.

DROOP: Means a drop or decrease in speed and/or voltage. A certain amount of speed droop is desirable to prevent hunting. Voltage must be allowed to droop with plants connected in parallel to lagging power factor loads but it must be balanced to allow proper sharing of the load.

GOVERNORS: Engine governors must be of the type which allow speed droop--isochronous and vacuum compensated types do not allow sufficient droop and cannot therefore be used in parallel operation.

HUNTING: Alternate increase and decrease in speed caused by insufficient speed droop characteristics in parallel plants.

INCOMING: The plant that is connected in parallel to a plant already in operation is called the incoming plant.

INDUCTIVE LOAD: Current lags behind voltage--also called lagging power factor load.

ISOCHRONOUS: Means equal in length of time. Isochronous type governors maintain constant speed regardless of changing load.

LAGGING: Refers to load condition where current is out of phase or lags behind voltage.

PARALLEL: Two or more electric plants operated and connected together to a common load.

PHASE SEQUENCE: Order in which voltage appears at output terminals. Also referred to as phase rotation.

POWER: Active power and reactive power are terms often used in describing parallel operation. Active power refers to the actual power delivered to the load or the KW output of the plant. Reactive power describes internal voltage differences between plants in parallel--the power created does no useful work but must be considered as it can affect actual or active power output.

POWER FACTOR: Unity power factor applies to circuits where current and voltage are in phase--the true power (watts) of a unity power factor load (unity = 1) is arrived at as the product of amperes x volts. Unity PF are pure resistance type loads. When current and voltage are out of phase, the power factor is calculated at less than 1, for example, a .8 PF rating is frequently used to describe average reactive type loads such as those imposed by motors.

RELAY - REVERSE POWER: Protective device to disconnect plants from parallel in the event of malfunction.

SOURCE: Incoming source indicates plant placed in parallel with another operating plant.

SYNCHRONIZATION: Phase, frequency and voltage of plants must be matched before they are placed in parallel. This can be accomplished manually with synchronizing lights or automatically with special synchronizing equipment.

VOLTAGE: Plants to be paralleled must have means of adjusting internal voltages. Rotating armature plants cannot be paralleled because internal voltages cannot be adjusted.

WATTMETER: Device for measuring active power output of a parallel plant. Ammeter reads reactive power of plants in parallel.

KOHLER

GENERATOR SETS

KOHLER CO.
Kohler, Wis. 53044

ES-914 2/73 U Class IV

KOHLER Technical Publications
PRINTED IN U.S.A.

T I Series No. GE-1

TECHNICAL INFORMATION

KOHLER
ELECTRIC PLANTS
World-Wide

GENERATOR

ROTATING ARMATURE

DIRECT CURRENT

KOHLER CO. - KOHLER, WIS.

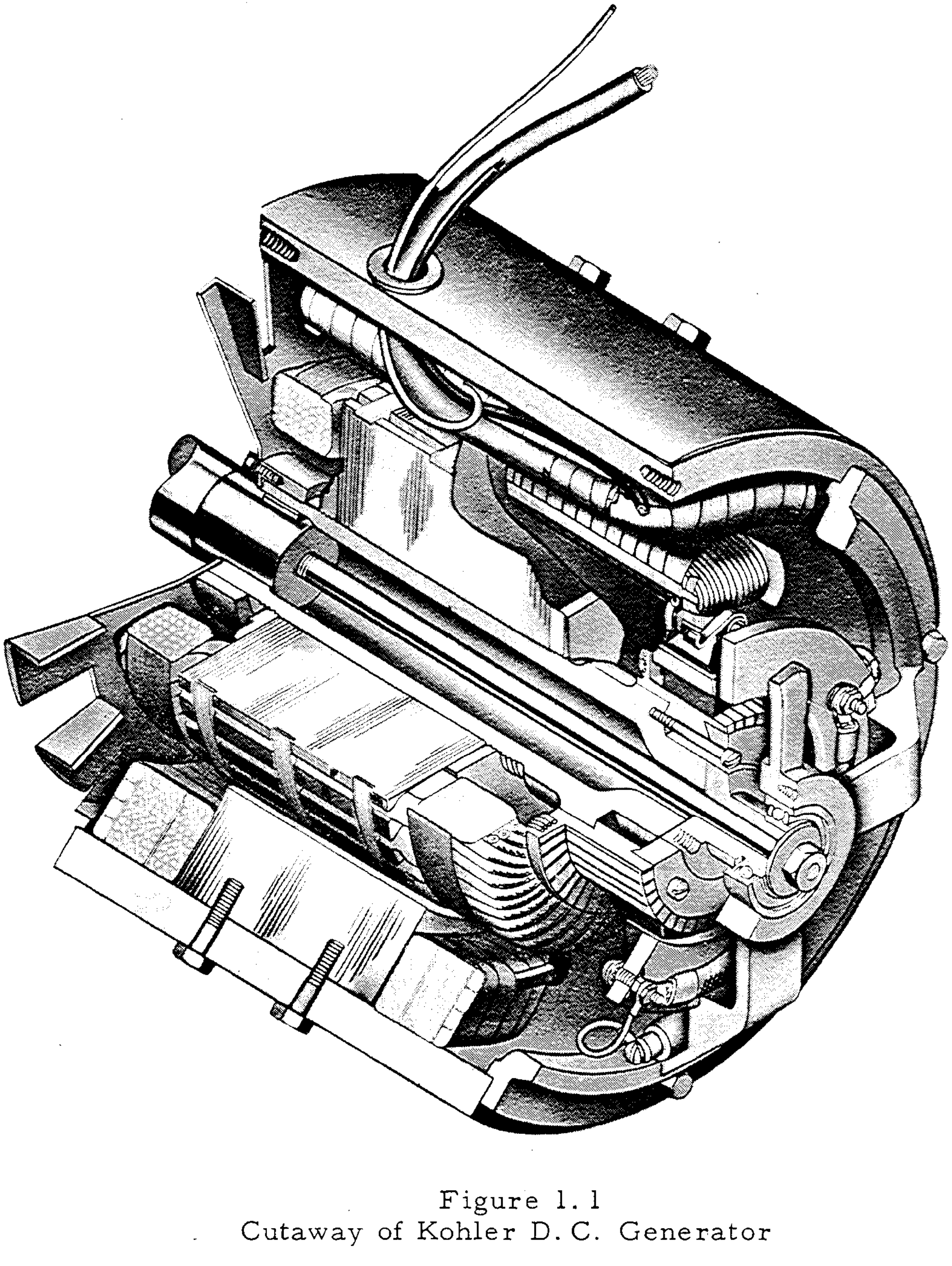


Figure 1.1
Cutaway of Kohler D.C. Generator

GENERATOR

ROTATING ARMATURE

DIRECT CURRENT

D. C. generators are of three major types:

1. Series wound.
2. Shunt wound.
3. Compound wound. (Which is a combination of the features of both).

Kohler D. C. generators are divided into two general classifications:

1. Battery charging generators.
2. Compound generators.

TYPES

All D. C. generators are of the revolving armature type because they require a commutator to rectify the alternating current induced in the armature coils. Most battery charging generators are built as straight shunt wound machines ranging in size from 500 watt to 10 KW at voltages of 7, 14, 28, 36 and 140 volts. Some generators in these sizes are combination machines in which part of the output is used to charge the battery and part to supply a load directly from the generator. The shunt wound battery charging generator with four brushes riding on the commutator is the most common type.

SERIES WOUND GENERATOR

The series wound generator is the simplest type generator; however, it is not a practical machine and therefore is not used. In order to better understand the series windings, we will begin our discussion with this type generator.

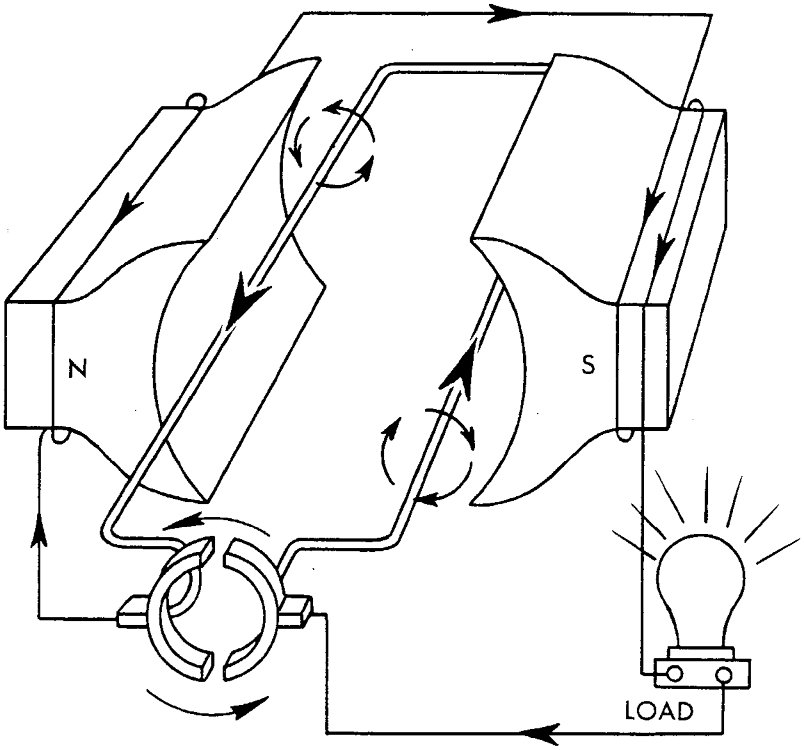


Figure 1.2
Series Wound Generator
This type generator is never used.

In the series wound generator the entire armature current passes through the field coils. When the armature is first revolved there is no current flowing in the field windings; however, there is a small voltage induced in the armature windings due to the residual magnetism in the core of the field magnet. This "residual voltage" is the factor that causes current to start flowing through the field windings and the external circuit. The field magnetism as well as the voltage induced in the armature windings builds up very rapidly at first. But as the field frame nears its saturation point the voltage and current will become constant. With the generator operating at constant speed the voltage and

CURRENT VARIATION

current from a series generator varies with every change in resistance of the external circuit, since each current change in the external circuit alters the field magnetizing current and consequently the voltage induced in the armature. Because of this variation, the series wound generator is very seldom used and is never used in Kohler generators.

SHUNT WOUND GENERATOR

The shunt wound generator differs from the series machine in that the field windings are connected across (or parallel to) the armature circuit instead of in series. Thus when the current leaves the armature through the positive brush, two paths are provided: One to the external circuit and the other to the field windings.

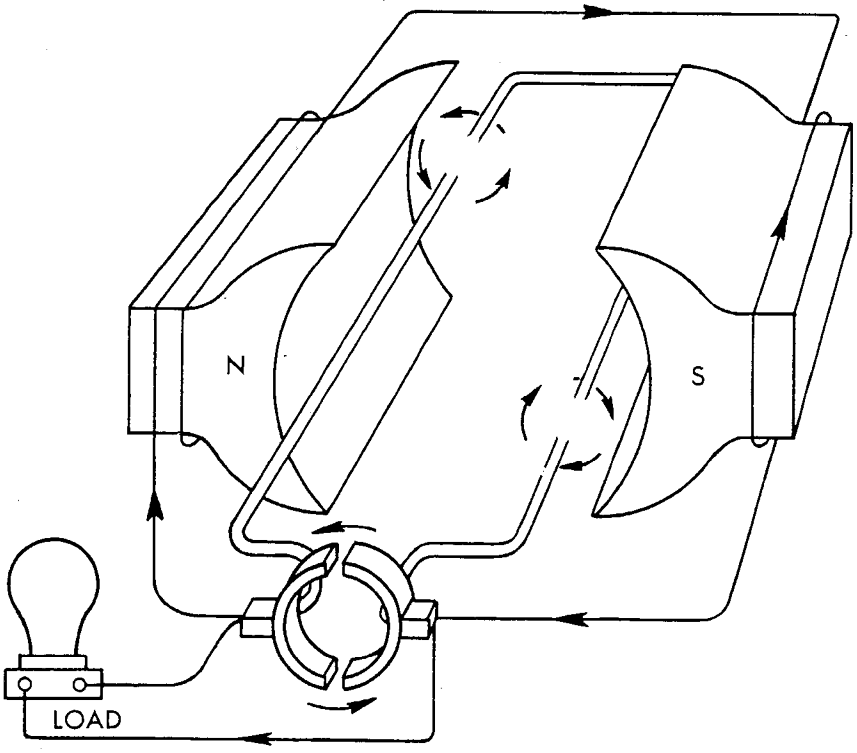


Figure 1.3
Shunt Wound Generator
Load is connected in parallel
with field windings.

PARALLEL CIRCUIT

Since the field coils in a shunt generator are wound with a large number of turns of fine insulated wire the resistance of the field circuit is high compared to that of the external circuit. The current divides between these circuits with the majority of current flowing in the path of least resistance or the external circuit. Because the resistance of the shunt field circuit remains constant, the current flowing through the field coils will be directly proportional to the voltage induced in the armature.

As the armature starts to revolve the armature windings cut the lines of force in the residual magnetic field between the pole pieces and generate a small residual voltage in the armature circuit. This causes a small current to flow through the shunt field windings intensifying the field magnetism. As the field magnetism increases and the armature windings cut more lines of force at increasing speed, the induced voltage at the armature increases. This voltage build up occurs rapidly at first, but after the field poles become "saturated" magnetically further increases in voltage are in direct proportion to the armature speed.

As load is increased the external circuit resistance is decreased. As we saw above the current seeks the path of least resistance and therefore additional current will be routed through the external circuit. The shunt field current remains directly proportional to the line voltage. As load is added current increases in the external circuit and armature.

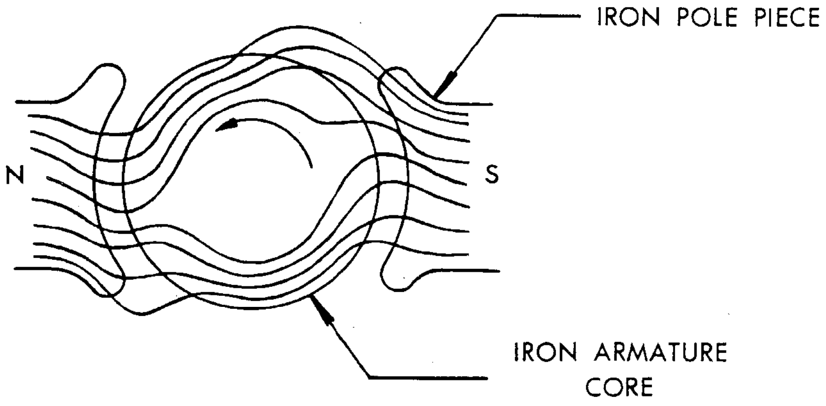


Figure 1.4
Magnetic Flux Distortion

The increased current in the armature distorts the magnetic flux in the field resulting in a drop in voltage output in the external circuit. For this reason we get a higher voltage at no load in a shunt wound saturated pole machine.

BATTERY CHARGING

Most Kohler battery charging plants have a rheostat in the shunt field circuit to adjust manually the charging rate by varying the shunt field current. Battery charging is possible only when the generator voltage is more than the battery voltage.

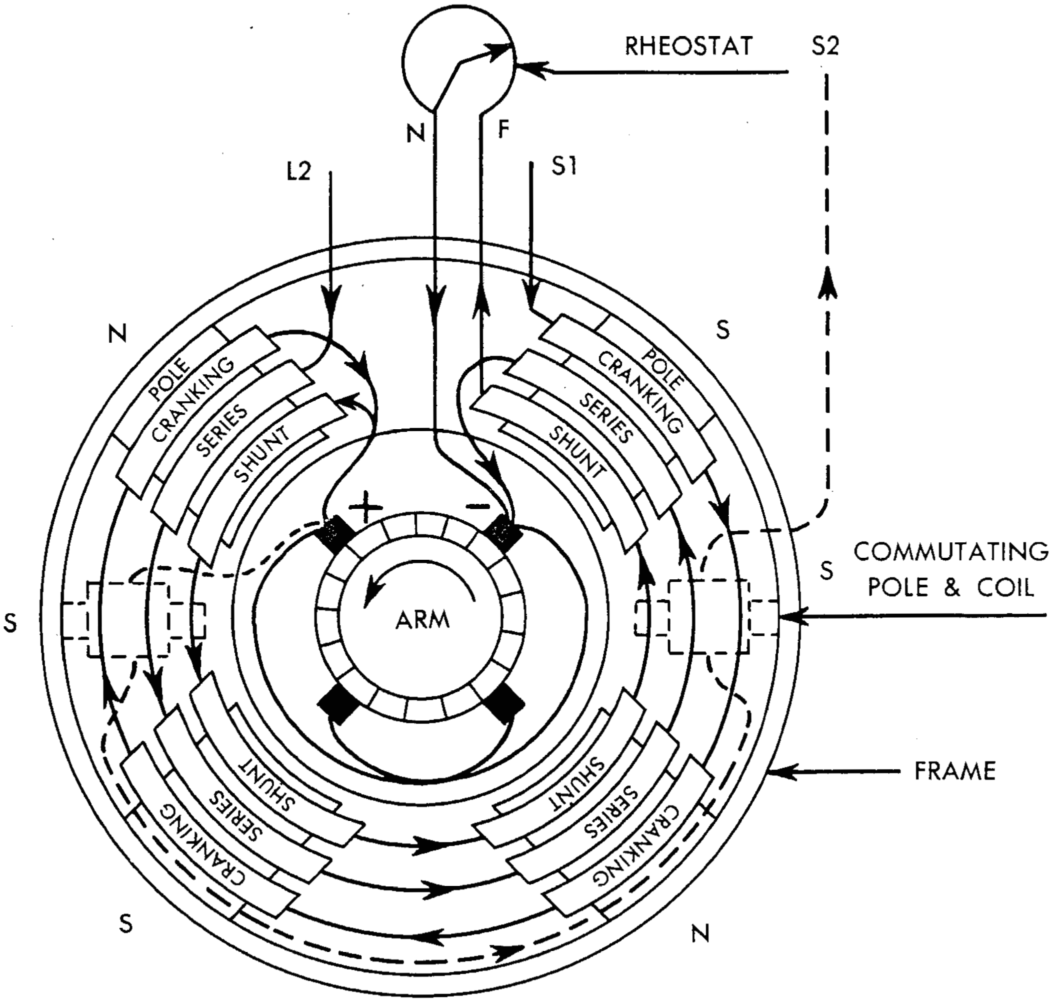


Figure 1.5
Battery Charging Generator
Dotted line shows commutating windings as a separate series winding.

The generator voltage can be adjusted by changing the current in the shunt field by means of the rheostat. Adding resistance in the shunt field circuit with the rheostat decreases the generator voltage because less current flows in the field. Therefore the battery charging rate is lowered. Starting from the plus or positive generator brush current flows through the coils of the shunt field through the rheostat and to the minus or negative brush. Battery charging current flows from the positive generator brush to the positive battery terminal through the battery from the negative battery terminal to the negative generator brush.

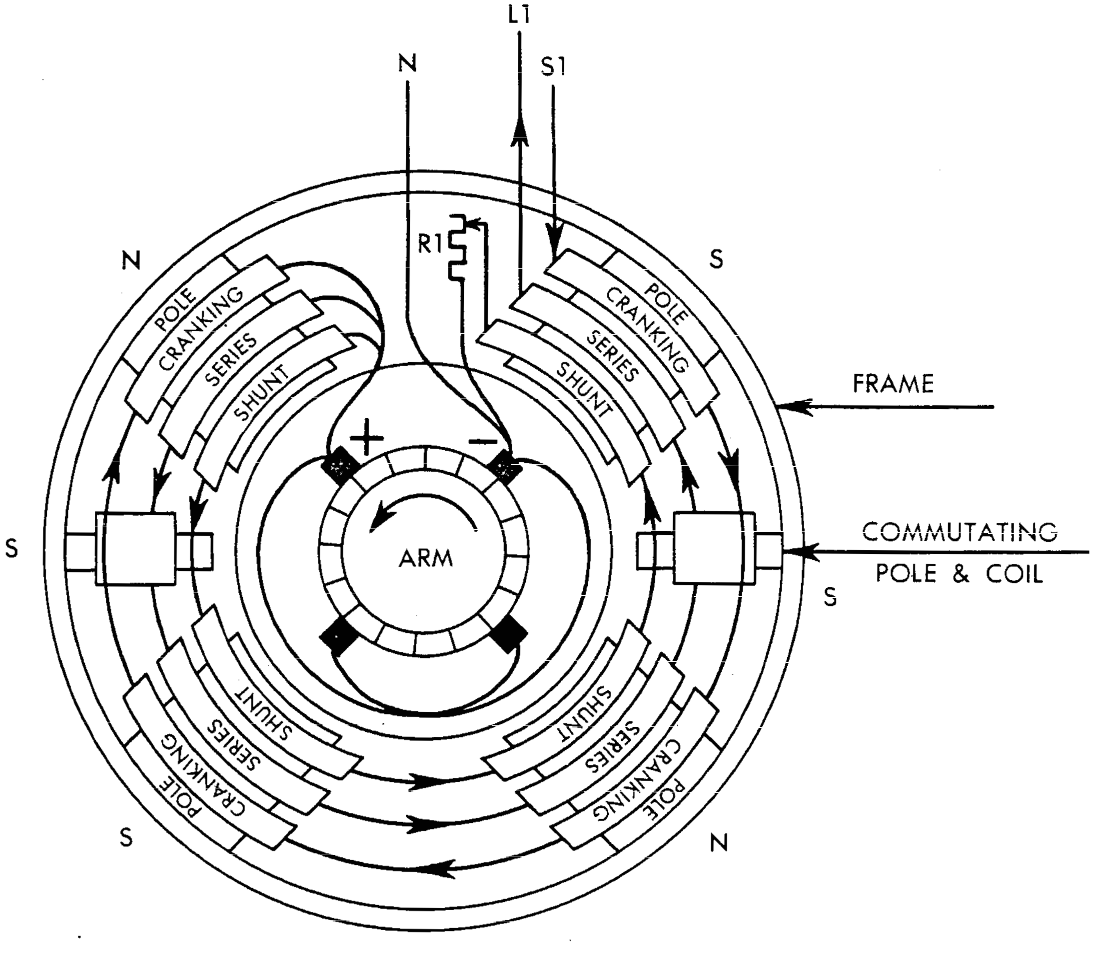


Figure 1.6
Compound Wound Generator
The series and parallel windings may be traced out above. Note that the commutating circuit is in series with the series winding. The cranking winding is used only for starting.

COMPOUND WOUND GENERATOR

The compound generator has two windings on each pole, one winding being connected in series with the armature circuit and the other being connected in parallel. Thus, it has the combined characteristics of both the series and shunt generator.

SERIES AND SHUNT WINDINGS

As previously stated the current through a shunt field winding is proportional to the voltage, and the current through a series field winding varies with the current through the external circuit. If the external circuit is open the compound wound generator builds up in the same manner as a shunt wound generator. A drop in armature voltage (because of increased load) and a consequent decrease in field strength (due to decrease in current through the shunt winding) is compensated for in the compound generator by the increase in current through the series winding.

If the magnetic power of the shunt and series windings of the compound generator is correctly proportioned, the drop in voltage which occurs in a shunt generator will be compensated for by an increase in field magnetism due to the series winding. This maintains constant voltage at the generator terminals.

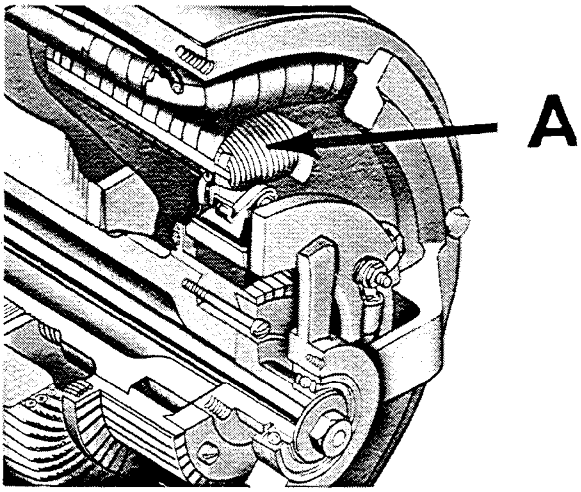


Figure 1.7
Commutating Pole
The cutaway above shows the position (A) of the commutating pole in D. C. generator.

COMMUTATION

Many times commutation becomes a problem because of high and varying currents and voltages. This condition is indicated by arcing of brushes, heating and wear of the brushes and commutator. These conditions can be corrected by including commutating poles or interpoles in the machine. The commutating poles, coils and leads are shown in the illustration.

COMMUTATING POLES

The commutating pole is made of soft steel with a few turns of large wire wound around it. As the load increases or decreases, a magnetic field is induced under the interpole in proportion to the load current.

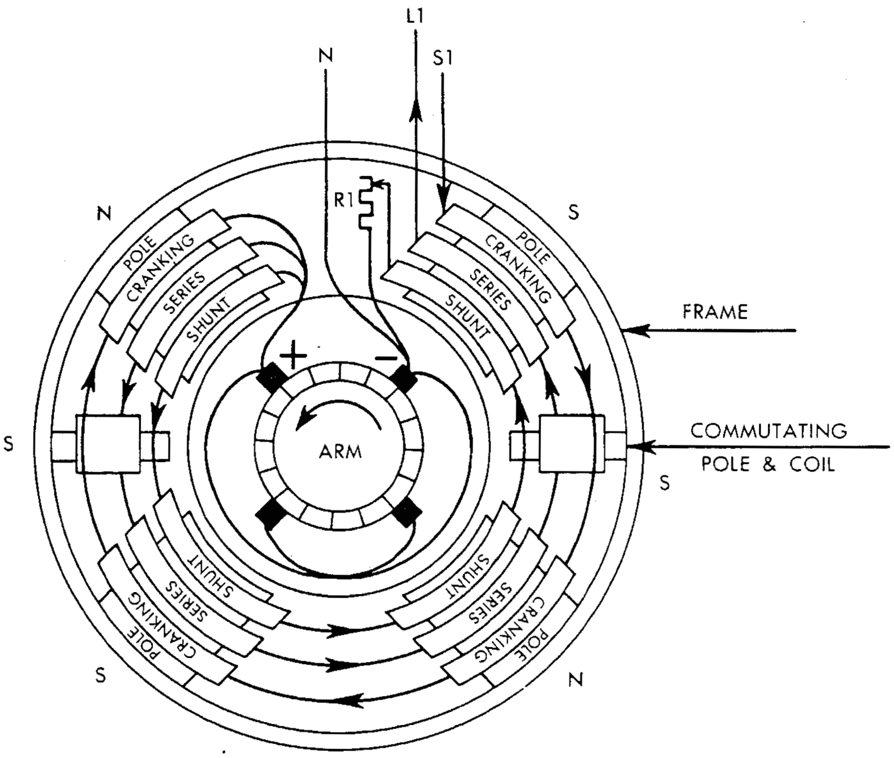
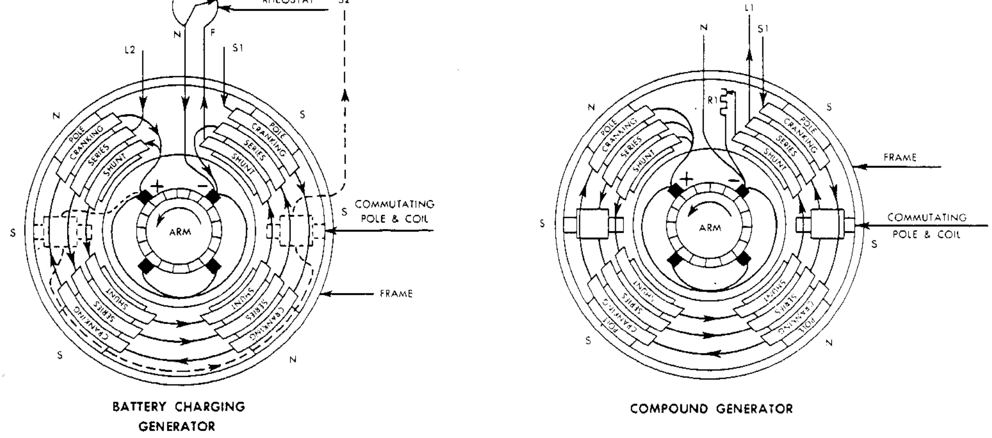


Figure 1.8
Commutating Pole Polarity
Polarity of commutating pole is opposite of that of the main pole preceding it in the direction of rotation.

As the armature current increases the magnetic field is distorted in the direction of rotation and the neutral no load position of the brushes changes. The commutating poles are placed between the field poles with the polarity of the commutating pole opposite to that of the main pole preceding it in the direction of rotation. The function of the commutating pole is to act against the distortion of the magnetic field caused by the armature reaction and enable the brushes to remain in a stationary neutral position. This position is usually the point on the commutator in line with the field pole bolts. Two commutating poles are included in all generators that require them.

NEUTRAL ZONE

To set the brushes on D. C. generators without interpoles, move the brushes ahead of the neutral zone in the direction of rotation of armature. As load increases the neutral zone moves in the direction of rotation. The usual practice is to find the position of least arcing when the generator is carrying about 75% load.



BATTERY CHARGING GENERATOR

COMPOUND GENERATOR

Figure 1.9
D. C. Generators
A comparison of the two types of Kohler
D. C. generators is shown above.

The illustrations show circuits for battery charging and compound generators. Note the difference in the connection of the commutating poles.

BRUSHES

Brushes play an important part in D. C. generator performance. On low voltage, high current machines low resistance brushes are required which contain as much as 70-80% copper. At the other extreme of high voltage, low current, highly resistant 100% graphite brushes are used. There are many combinations of brush material between these two extremes.

MAINTENANCE

Since many of the D. C. generator troubles start in the commutator, periodic cleaning and checking of brushes and commutator will keep the generator in good running condition. If a machine with interpoles develops a condition of bad arcing, it may not be brush trouble but a shorted interpole winding or an interpole of wrong polarity.

T I Series No. GE - 2

TECHNICAL INFORMATION

KOHLER
ELECTRIC PLANTS
World-Wide

GENERATOR

ROTATING ARMATURE

ALTERNATING CURRENT

KOHLER CO. - KOHLER, WIS.

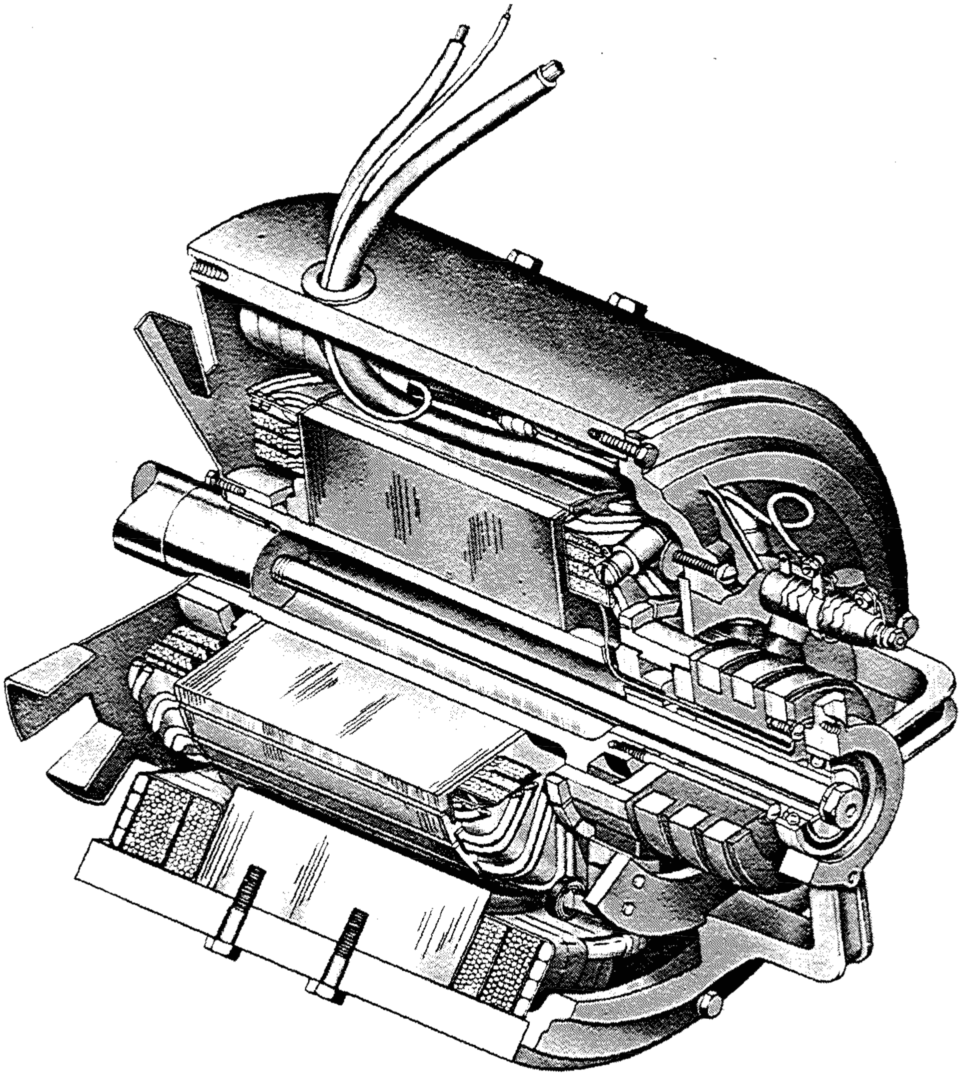


Figure 2.1
Cutaway of Rotating Armature
A.C. Generator

GENERATOR

ROTATING ARMATURE

ALTERNATING CURRENT

A. C. GENERATORS

The rotating armature type of A. C. generator has been built at Kohler for many years. As the name implies, the armature rotates and the field is stationary. The generators in this class range in size from 500 watts to 15,000 watts or 15 KW. All rotating armature A. C. generators are actually two generators, A. C. and D. C., combined in one frame using a common magnetic circuit.

SHUNT FIELD

Illustration 2.2 is a type of generator frame associated with our manually started plants in the smaller sizes. We will start our discussion with this generator because it is the simplest A. C. generator in our line. The armature includes two sets of windings placed in the same armature slots. The outer or D. C. winding is connected to the commutator bars and its only purpose is to excite the field with D. C. current. The field current flows from the plus brush through the shunt field coils, to the negative brush. This is called a shunt generator as determined by the way the field circuit is shunted across the armature.

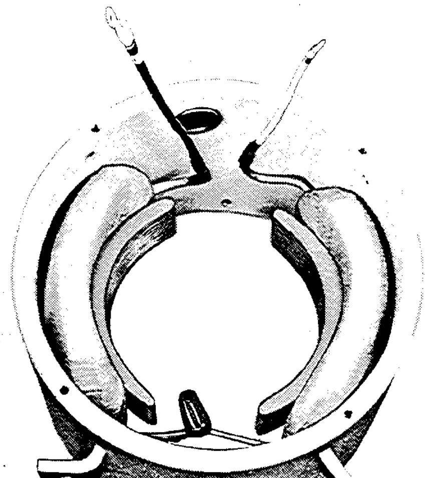


Figure 2.2
Two Pole Generator Frame
Note heavy iron frame and
laminated field poles.

The above circuit may be traced out in figure 2.3.

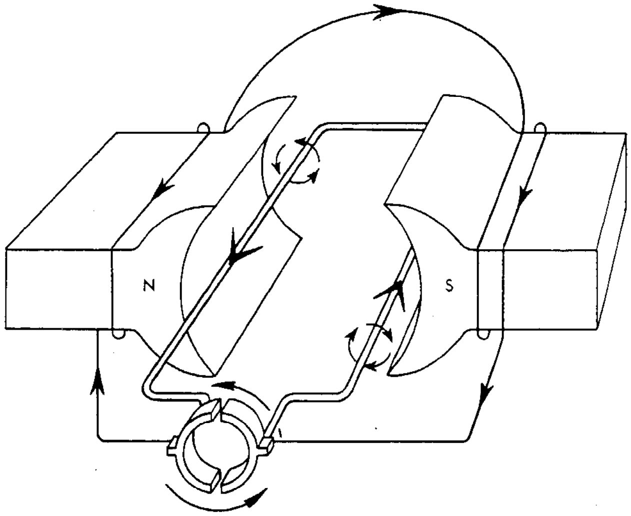


Figure 2.3
Shunt Field Winding

The 1500 watt generator is designed for 3600 RPM operation and is of 2 pole construction. Generator designs for 1800 RPM operation have 4 poles. The relationship between RPM, field poles and A. C. frequency will be discussed later.

LOSS OF MAGNETISM

Normally there will be enough residual magnetism in the field poles to start the build up of voltage in the exciter armature. Occasionally a manually started plant will lose its magnetism and fail to build up voltage. When this happens it is necessary to "flash the field" with a battery. This is accomplished by lifting the brushes from the generator while the plant is at rest and simply connecting the positive terminal of the battery to the positive D. C. generator brush and momentarily connecting from the negative post of the battery to the negative D. C. brush in the generator.

CRANKING

CRANKING SERIES FIELD

Exciter cranked generators form another type of generator used in the push button, remote, and automatic started electric plants. This feature requires the addition of another field winding called the cranking series or cranking field. This field is connected in series with the armature. It changes the D. C. shunt generator while cranking to a series D. C. motor having a very high torque for cranking the engine. In principle this is the same type of starting motor as used in engines with automotive type starter and ring gear.

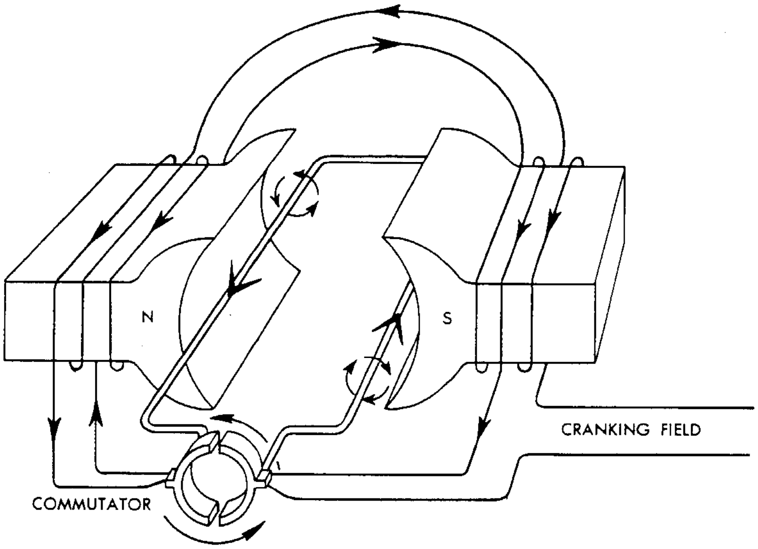


Figure 2.4
Cranking Field
The cranking field is wound in the opposite direction to the shunt field winding.

The cranking series winding consists of a few turns of heavy wire around each of the field poles. These turns of wire must be capable of carrying high D. C. currents which are present during cranking. As soon as the engine fires and runs under its own power the series circuit is opened. Thereafter while the engine is running and the generator is producing current for the load, current no longer flows in the cranking series field coils.

CURRENT FLOW

The illustration shows the direction of current in the cranking winding and also that the winding is in series with the armature. Starting at the battery positive terminal, current flows through the cranking fields and the armature windings, to the negative battery terminal. You may notice that the direction of current flow is opposite to the shunt and auxiliary fields. This condition would cause the magnetic field to reverse its direction during cranking. To prevent this the cranking field is wound in the opposite direction to the shunt and auxiliary field.

A generator with a cranking winding does not have to be "flashed" to build up voltage since the cranking of the generator magnetizes the field in the proper direction each time it is cranked.

ARMATURE CONSTRUCTION

A. C. WINDINGS

In our discussion of rotating armature A. C. generators to this point, most of the comments were about D. C. circuits for field excitation and cranking. Turning to A. C. windings we find that the inner coil of the armature shown on the drawing is connected directly to 2 collector rings. The magnetic field created by the exciter induces an alternating current in the A. C. armature

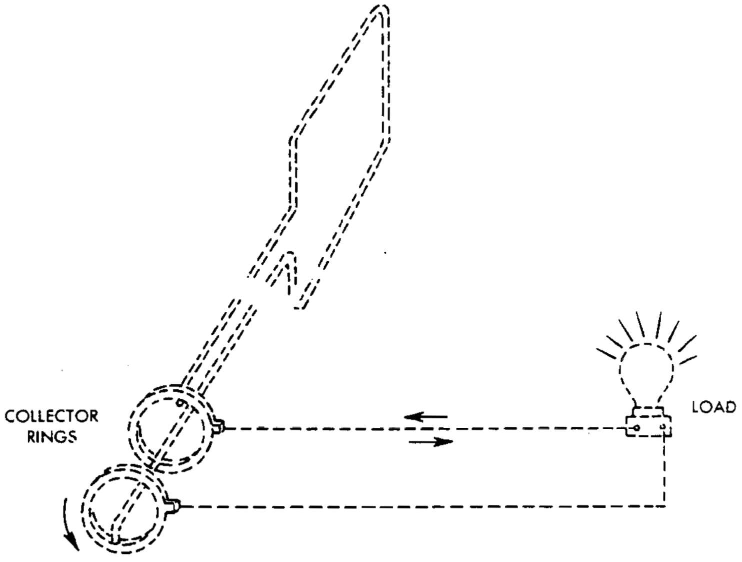


Figure 2.5
A. C. Armature Winding

SINGLE PHASE

windings. The generator shown is 2 wire single phase, suitable for 115 volts or 230 volts depending on the inner winding of the armature. A 115/230 volt single phase generator would normally require 3 collector rings as used on our 5 KW, 3 wire machines. This arrangement provides two circuits for 115 volts and one circuit for 230 volts in one generator.

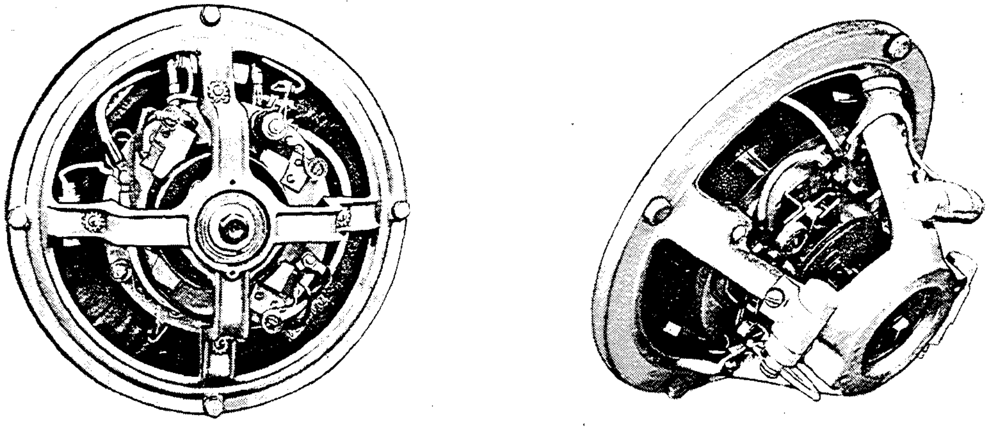


Figure 2.6
Generator End Brackets

Some 10 KW and 15 KW single phase armatures have 4 collector rings. By making the proper jumper connections on the brush ring, the double winding of the armature can either be parallelled or series connected resulting in either a 2 wire 115 volt, or a 3 wire 115/230 volt machine.

THREE PHASE

Three phase armatures have 3 separate windings, equally spaced in relation to each other. When connected to collector rings, the resulting voltage generated is three phase. A different armature is required for each type of 3 phase machine built. For example, a 3 phase 4 wire generator requires one collector ring for each phase and one for the neutral, which is the common connection of the three windings, or a total of 4 rings. Three phase 3 wire Delta connected generators have no neutral, so require only 3 collector rings. A 3 phase 3 wire generator can also be wye connected but in this case the common connection is made in the winding and no lead is brought out to a collector ring.

MAGNETIC CIRCUIT

The magnetic circuit requires a steel frame, field poles, and armature core. The poles and armature core are not solid pieces of steel, but are assembled or stacked steel laminations to keep heating and losses of the magnetic circuit to a mimimum.

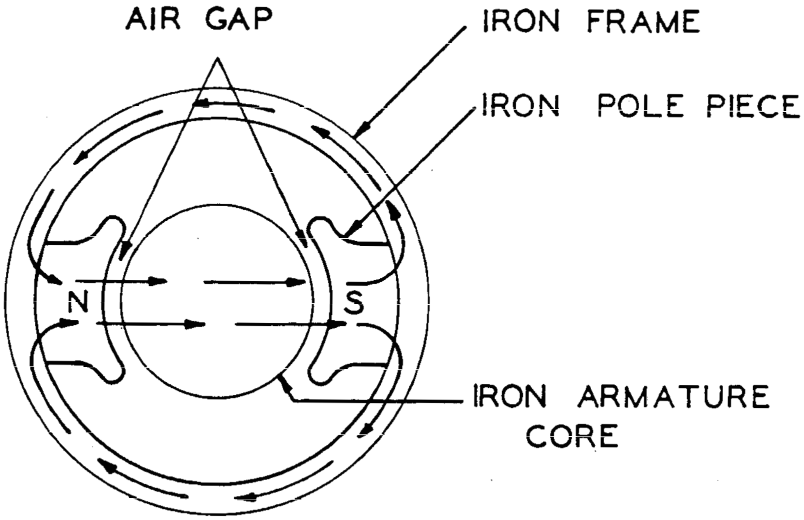


Figure 2.7
Magnetic Circuit
Illustration shows how generator frame is part of magnetic circuit.

The cross-sectional area of iron available throughout a magnetic circuit is important. The thickness of the frames of rotating armature generators is therefore usually more than would be required for mechanical strength. The illustration shows the path of magnetic flux.

VOLTAGE REGULATION

As load is increased on a generator, line current, or the A.C. current passing through the armature increases. This heavy A.C. current in the armature has a strong demagnetizing effect on the field. This causes a drop in line voltage.

SATURATED FIELD

Several methods are used for compensating for this drop in line voltage. There is a limit to the amount of magnetism which can be induced in a given field pole design. A field pole which is magnetized to its maximum is said to be saturated. A certain amount of voltage stability is inherent with a saturated field design and many of our small generators are of this simple type.

STEP RELAY

In our 1000 and 1250 watt plant, a different method is used to provide voltage stability. At approximately 1/2 the rated load, a relay closes a contact which shorts out the field resistor. This relay (s) is located in the end bracket of the generator. By reducing resistance in the field the excitation current is increased and the resultant stronger magnetic field stabilizes line voltage.

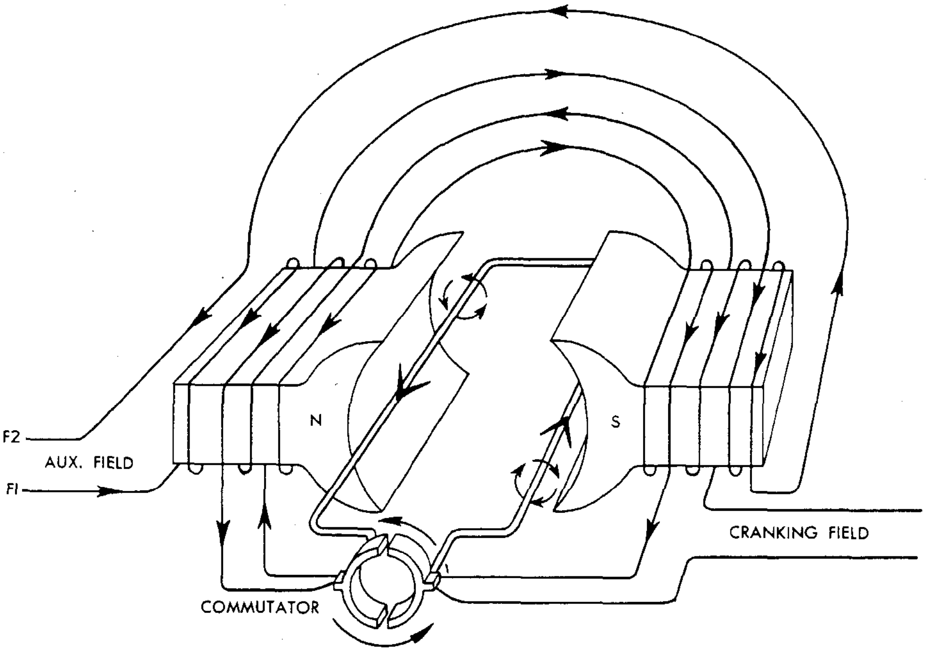


Figure 2.8
Auxiliary Field
The third winding is added
to the field coils.

AUXILIARY FIELD

On the larger rotating armature plants, from 5 KW - 15 KW, additional means is necessary for providing good voltage control. This is done by means of an auxiliary field. This field gets its current from the A. C. line. Line current passes through the primary side of a transformer. The secondary winding of the transformer feeds current to a bridge connected rectifier. D. C. current is fed from the rectifier to the auxiliary field coils in proportion to the amount of load on the line. The diagram indicates auxiliary windings and the field poles. The terminals which receive current from the rectifier are indicated as F1 and F2.

The auxiliary winding has the same effect on an A. C. generator as the series winding of a compound D. C. generator.

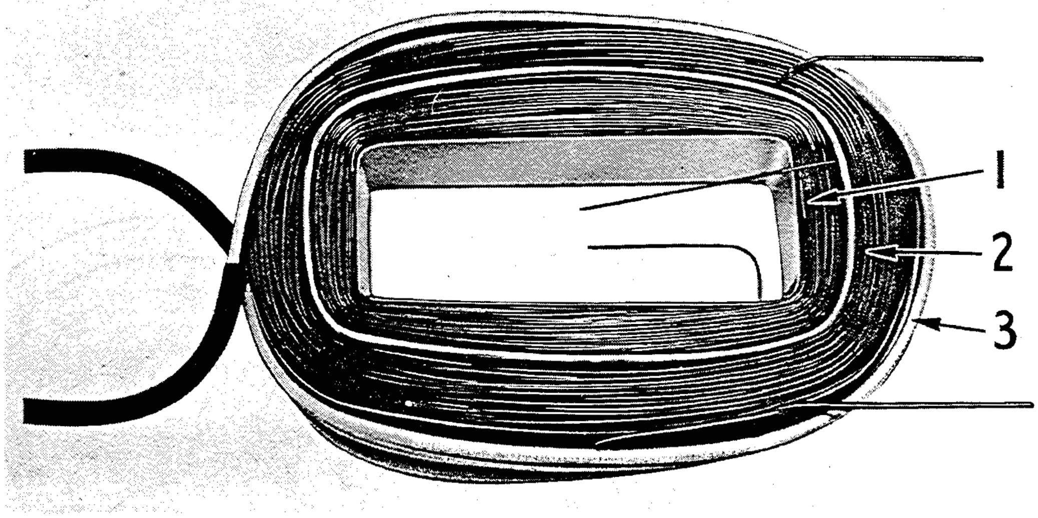


Figure 2.9
Field Coil
In this field coil with its wrappings removed, the three windings are easily seen.
1. Auxiliary Field. 2. Shunt Field. 3. Cranking Field

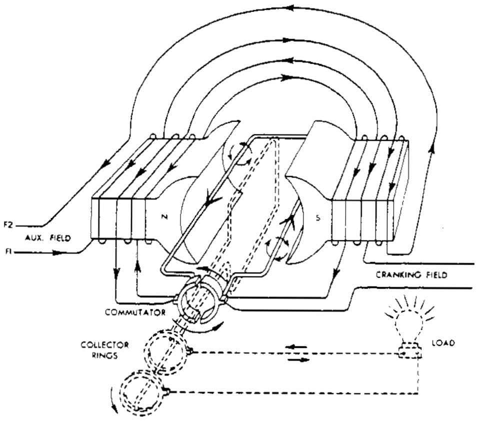


Figure 2.10
Rotating Armature A. C. Generator
This illustration shows the complete schematic of the rotating armature A. C. generator.

T I Series No. GE-3

TECHNICAL INFORMATION

KOHLER
ELECTRIC PLANTS
World-Wide

GENERATOR

REVOLVING FIELD

ALTERNATING CURRENT

KOHLER CO. - KOHLER, WIS.

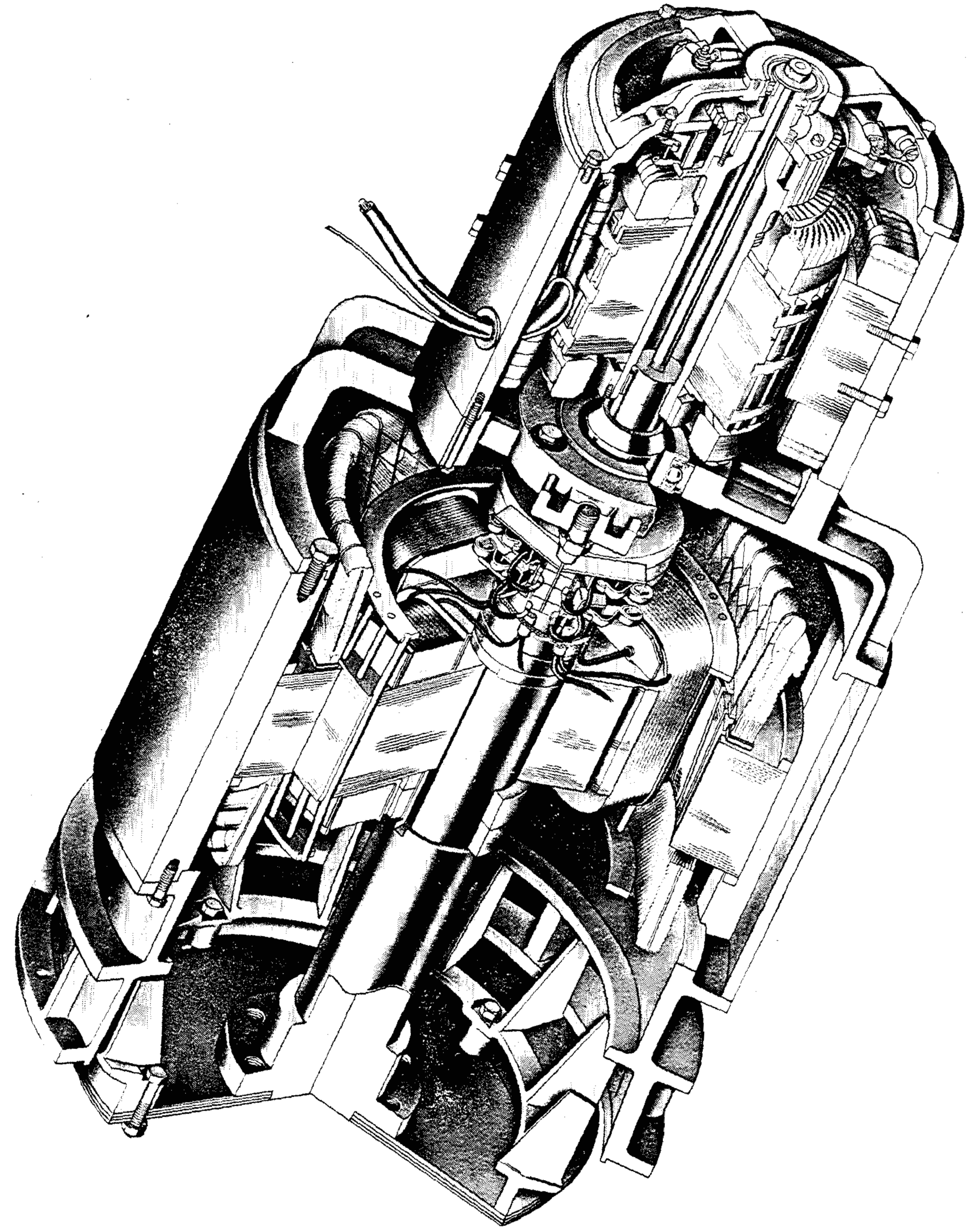


Figure 3.1
Revolving Field Generator
The illustration shows a complete revolving field generator consisting of a D.C. exciter and an A.C. alternator.

GENERATOR

REVOLVING FIELD

ALTERNATING CURRENT

The revolving field generator is used primarily in the larger electric plants--from 25 KW and larger. Its design is such that it does not require collector rings and brushes to carry the heavy line currents and high line voltages. Therefore, it is more adaptable for the larger electric plants.

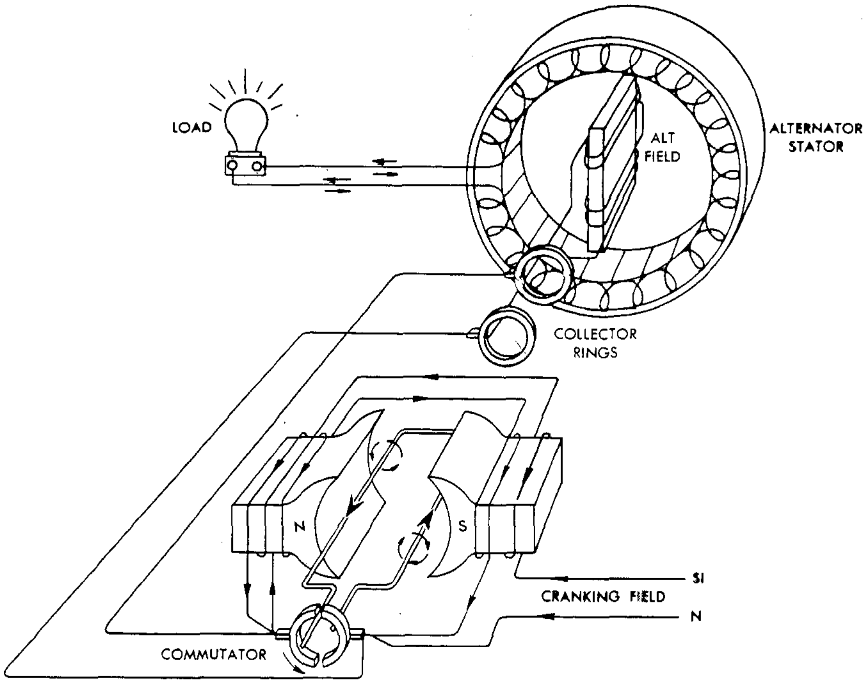


Figure 3.2
Revolving Field Generator
The schematic shows the D. C. exciter and its relationship to the A. C. alternator.

The essential elements of a revolving field generator are shown in the illustrations. Part of it can be recognized as a D. C. generator, the same as described under rotating armature D. C. generators.

The revolving field generator is actually two generators--D.C. and A.C. The D.C. portion is used for excitation of the field coils in the A.C. alternator. This D.C. exciter also contains the cranking windings and is used to crank the electric plant.

D.C. EXCITER

Revolving field alternators require an external source of current for exciting the rotor field. The revolving field is excited by the direct connected D. C. exciter.

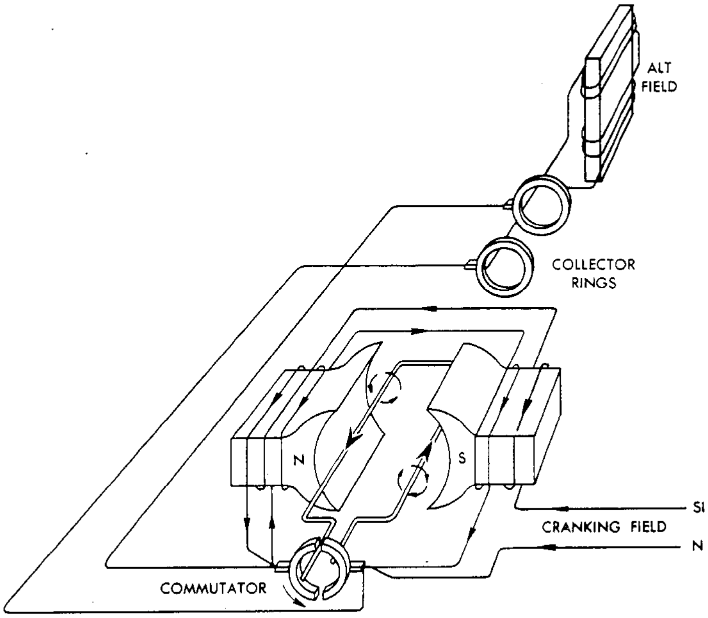


Figure 3.3
Exciter Circuit
The shunt field windings and the cranking field windings of the exciter are shown. The current produced in the armature is carried to the alternator field coils through the collector rings.

In the exciter we use two field windings. These are the shunt winding and the cranking winding. The current produced in the armature is transmitted through the commutator and routed to the collector rings which carry this current to the alternator field coils.

The cranking circuit works exactly the same as was discussed on the rotating armature type machine.

A.C. ALTERNATOR

The revolving field alternator is made up of a rotor assembly and a stator assembly. The rotor assembly contains the field coils and serves the same purpose as the generator frame and field poles of a rotating armature type generator. The stator is the armature of the revolving field generator. Rather than revolving as in the rotating armature type, it is stationary. The revolving field generator has basically the same components as the rotating armature except in different form.

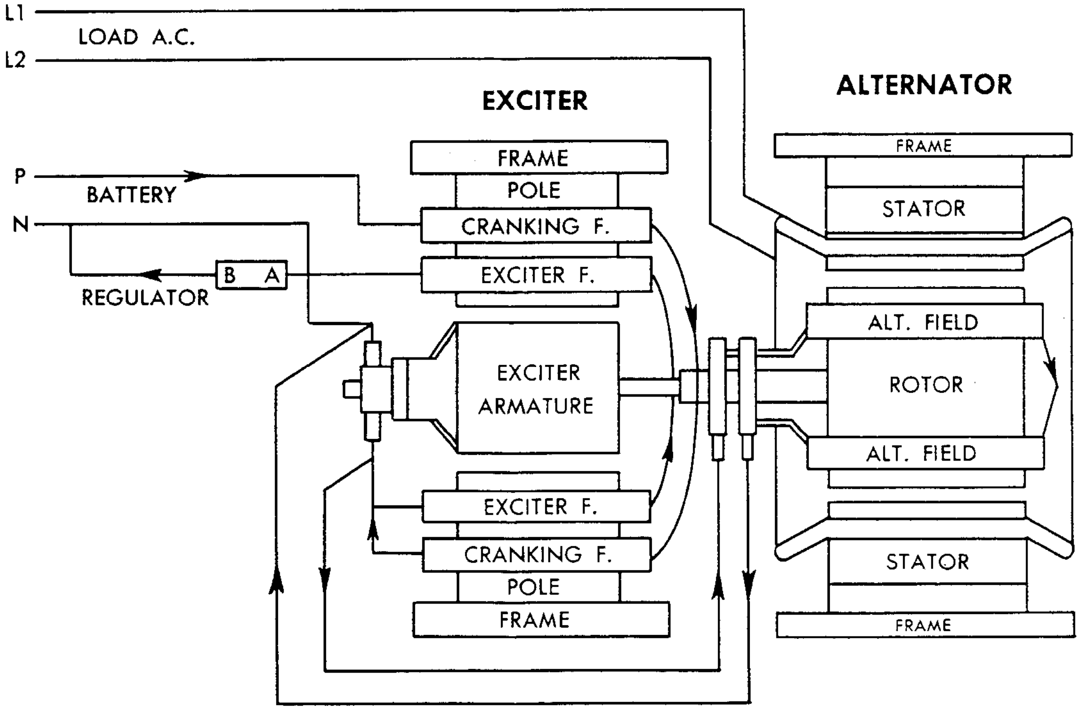


Figure 3.4
Revolving Field Generator Components
The illustration shows the arrangement of the components in the revolving field generator.

ROTOR

The rotor assembly consists of many steel laminations stacked together and welded. They are so shaped that the field coils can be wound directly on the poles. This field assembly is then pressed on a shaft together with a collector ring assembly. The four field coils are connected in series and the ends are fastened to the two collector rings. Since this rotor assembly moves at 1800 RPM all parts must be tightly held together.

The rotor assembly also includes a damper winding. This winding is made up of heavy copper bars imbedded in the pole faces. The ends of these bars are welded to heavy copper rings.

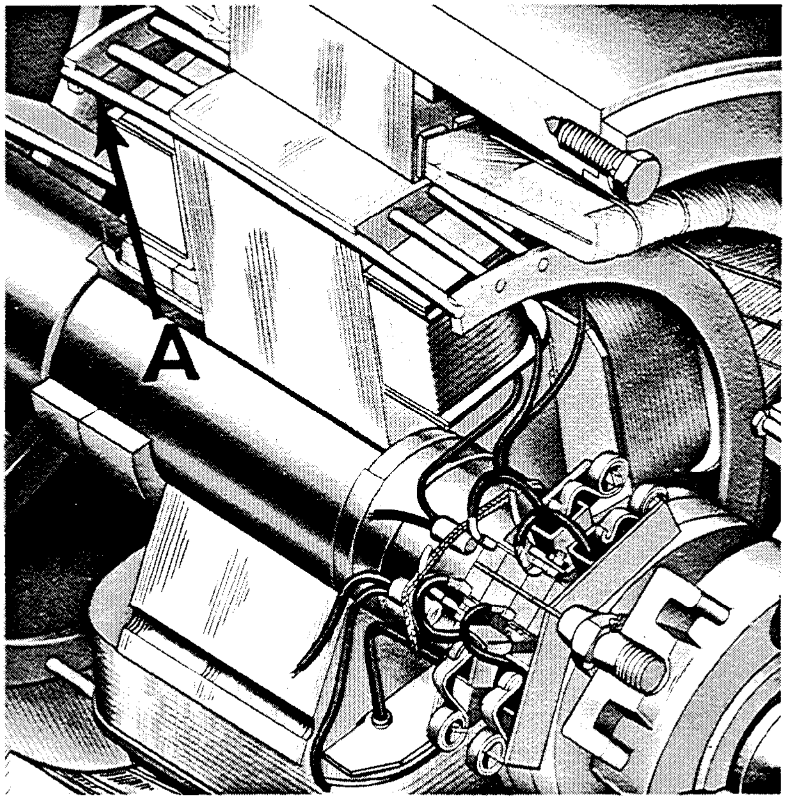


Figure 3.5
Damper Windings
The copper bars (A) can be seen together
with the copper rings welded on the ends.

DAMPER WINDINGS

Its purpose is to counteract the effect of single phase armature reaction which causes large eddy current losses in the poles. These losses show up in the form of heat. The damper windings reduce the tendency of the alternators to hunt when paralleling electric plants.

STATOR

The stator is the armature of the rotating field generator. It also is made up of steel laminations containing the proper number of slots for the stator winding.

Included in the stator assembly is a thin steel frame which is wrapped around the stator laminations. It is separated from the laminations by spacers to provide a path of air for cooling.

The armature or stator windings are located in the stationary part of the generator with leads routed out directly to the load. Being stationary, no brushes or collector rings are necessary between armature and load, therefore eliminating the brush problems which would otherwise be present with the high load currents experienced with large electric plants.

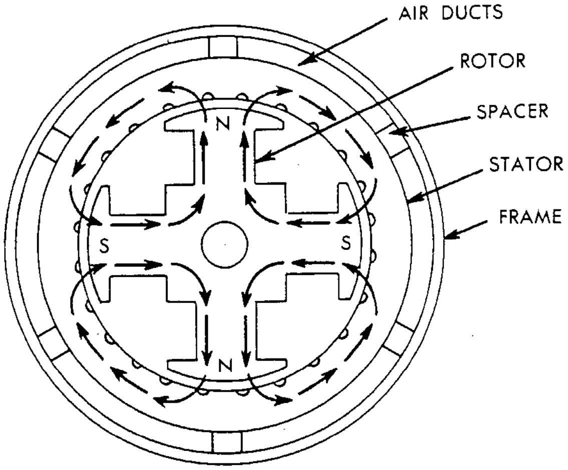


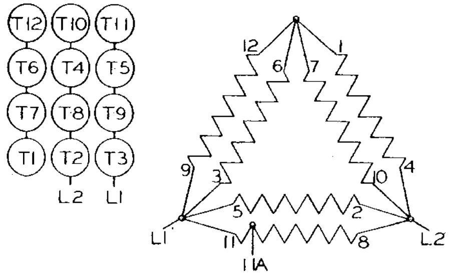
Figure 3.6
Alternator Construction
The illustration shows a general cross-section of the alternator. The arrows indicate the magnetic circuit.

MAGNETIC CIRCUIT

Illustration 3.6 shows lines of force flowing from North poles to South poles in four different paths. These lines of force always flow between adjacent poles. On a rotating armature machine the frame must be in the magnetic circuit. The frame of a revolving field generator is not required to carry lines of force which means it can be made of material other than steel if desired. Steel is used only to give strength to the mechanical structure of the revolving field generator.

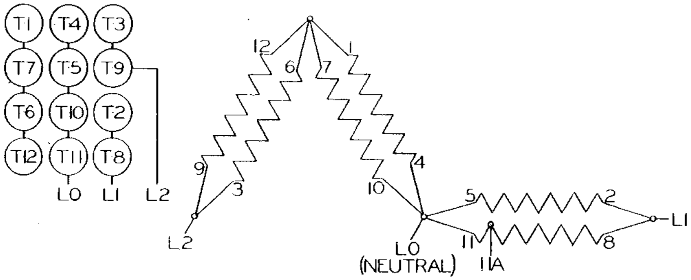
STATOR WINDINGS

The stator or armature windings of Kohler revolving field generators are constructed of six separate coils resulting in twelve separate connecting leads. These various coils are represented as shown in reconnection diagram No. B-262114. The positions of the coils in the generator determine the phase to which they belong. In the connection diagram the coil



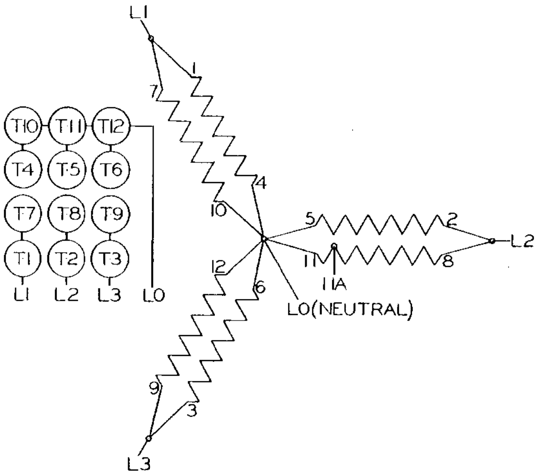
120 VOLT 1 PHASE-2 WIRE

FIGURE 1



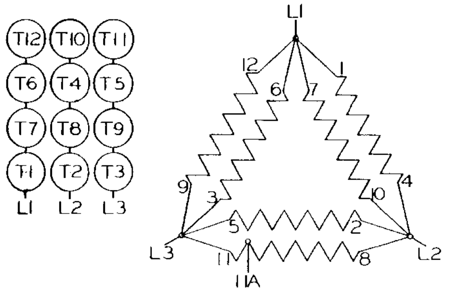
120/240 VOLT 1 PHASE-3 WIRE

FIGURE 3



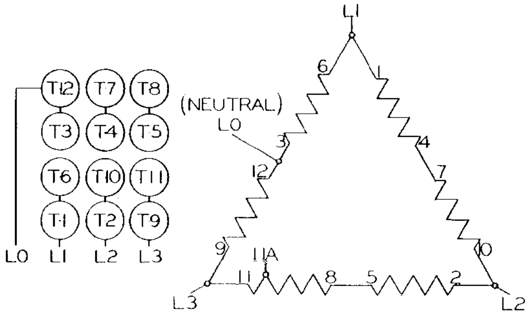
120/208 VOLT 3 PHASE-4 WIRE (SEE NOTE 4)
240 VOLT 3 PHASE-3 WIRE

FIGURE 4



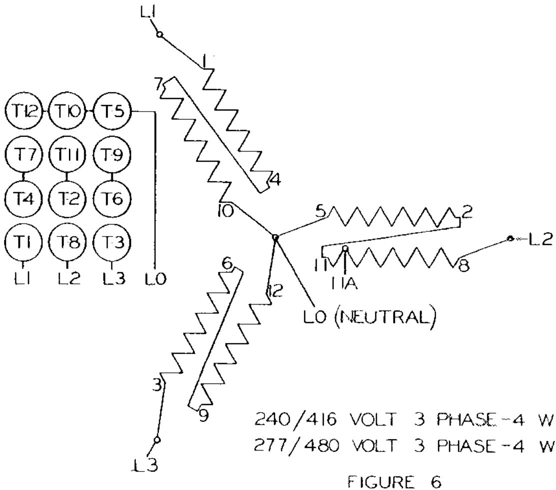
120 VOLT 3 PHASE-3 WIRE

FIGURE 2



120/240 VOLT 3 PHASE-4 WIRE

FIGURE 5



240/416 VOLT 3 PHASE-4 WIRE
277/480 VOLT 3 PHASE-4 WIRE

FIGURE 6

NOTE -- B-262114

1. Voltage regulator leads are connected to terminals 2 and 9.
2. Terminal 11A is used for controller circuit in place of terminal 11 on 240 volt 3 phase - 3 wire and 277/480 volt plants.
3. When using 120 volt connection (Fig. 1 or 2) the Regohm voltage regulator in the controller must be corrected for 120 volt operation by shorting out the non-adjustable resistor next to the regulator plug-in unit.
4. For 240 volt 3 phase - 3 wire previous to serial No. 230988 use Fig. 5 omitting terminal L0.

Figure 3.7

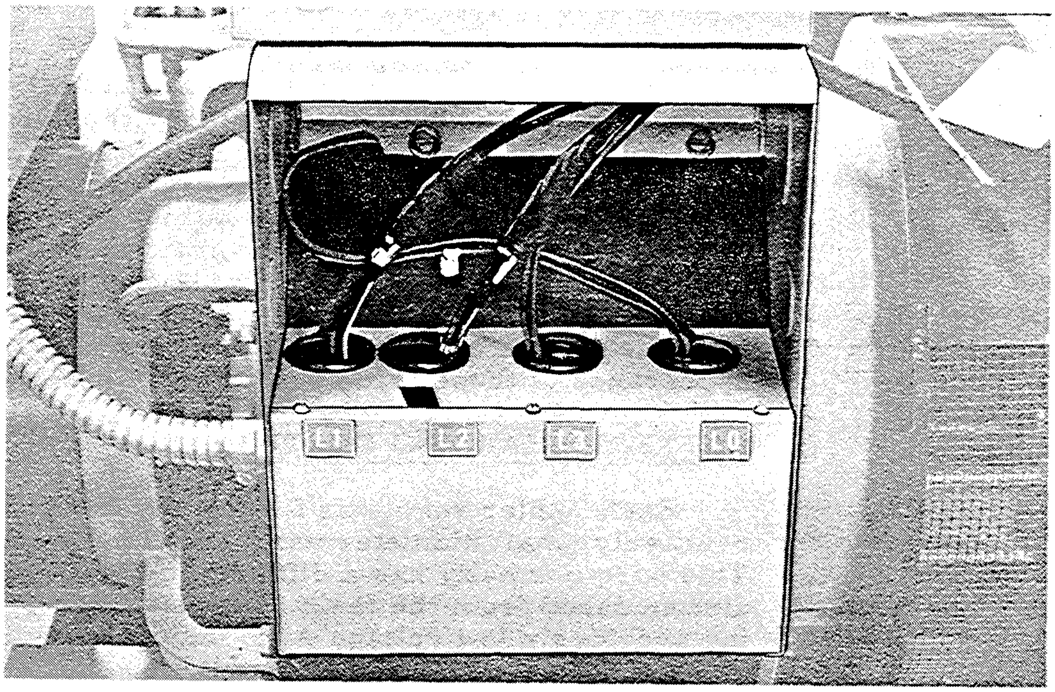


Figure 3.8
Generator Junction Box
Cover is in place showing generator lead designations L1, L2, L3 and L0.

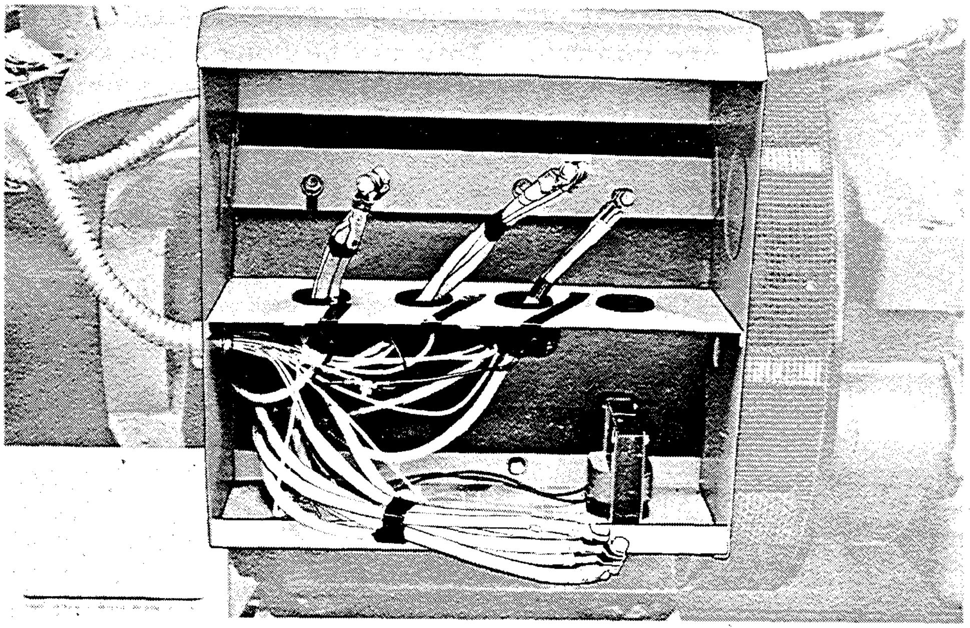


Figure 3.9
Generator Junction Box
Cover is removed showing placement of components in junction box.

PHASE AND VOLTAGE GROUPING

represented horizontally with terminals No. 5 and 2 is in the same phase as the coil represented with terminals No. 11 and 8. The coils at other angles on the diagram are of a different phase relationship than the two just mentioned. The grouping of the leads for various voltage combinations may be accomplished by following the illustrations on diagram B-262114 and by following the instructions on the reverse side of the diagram. The leads are usually grouped at the factory to give the voltage specified on a customer's order. The illustrations 3.8 and 3.9 show the appearance of these leads as the plant is shipped from the factory.

BATTERY CHARGING FEATURE

Each Kohler revolving field generator has a few turns of relatively small diameter wire built into the alternator stator. This wire normally has a different color insulation and is readily distinguished from the main alternator coil. This special winding provides a low voltage A. C. output to be used for battery charging after being rectified in the controller.

BATTERY CHARGING CONNECTIONS

The battery charging leads are 15, 16, 16A and 17. Lead 15 is common and is always connected to terminal 15 in the controller. Lead 16 is normally used for battery charging and is connected to terminal 16 in the controller. In the case of 36 volt plants it is sometimes necessary to increase the battery charging voltage. This can be done by disconnecting controller lead 16 from generator lead 16 and reconnecting to either generator lead 16A or 17.

T I Series No. GE-4

TECHNICAL INFORMATION

KOHLER
ELECTRIC PLANTS
World-Wide

GENERATOR

FREQUENCY

VOLTAGE REGULATION

TEMPERATURE RISE

EXCITER CRANKING

WIRING DIAGRAM REPRESENTATION

FIELD DATA

TROUBLE ANALYSIS

KOHLER CO. - KOHLER, WIS.

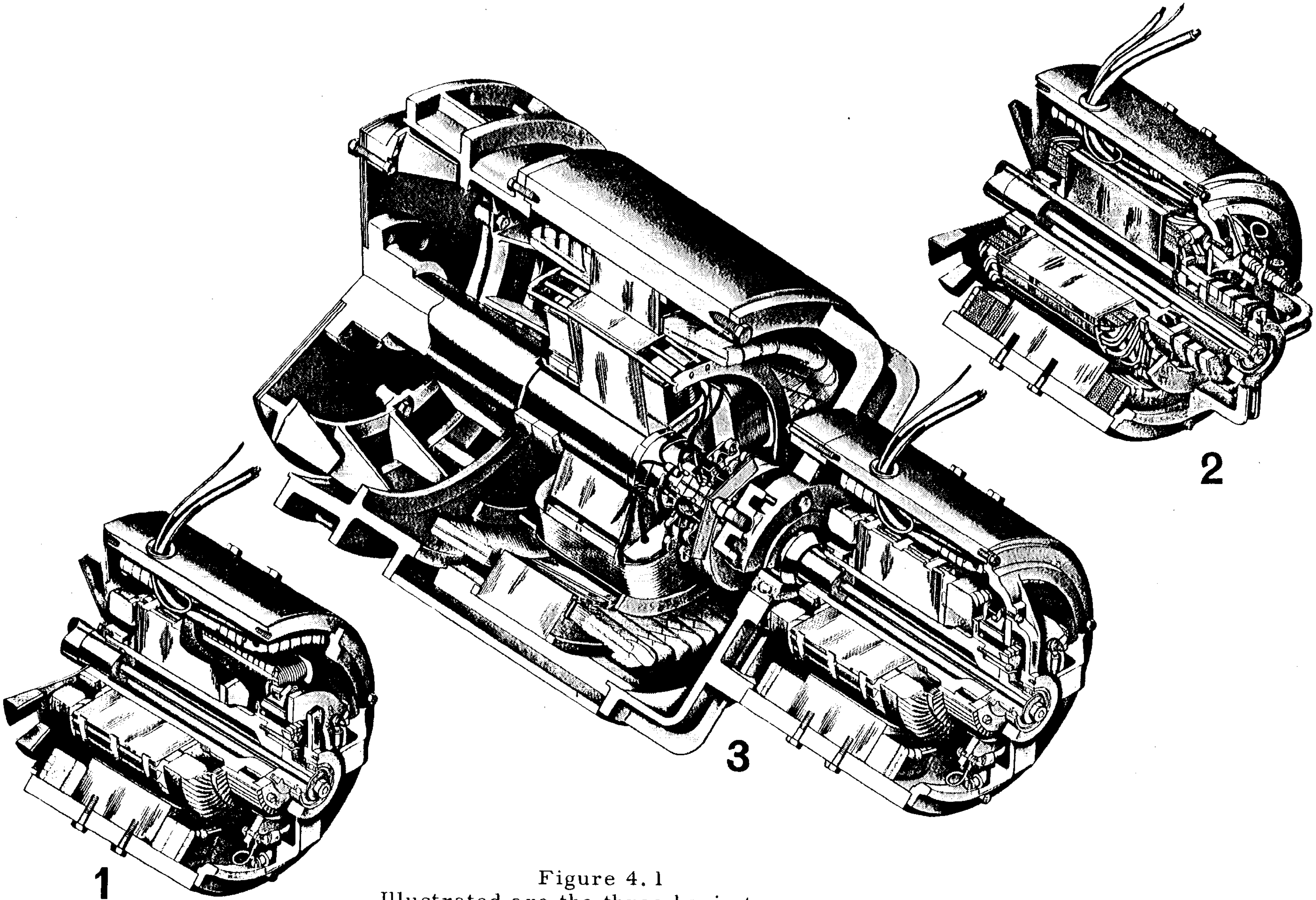


Figure 4.1
Illustrated are the three basic types
of generator manufactured by the
Kohler Co.

1. Rotating Armature - Direct Current
2. Rotating Armature - Alternating Current
3. Revolving Field - Alternating Current

GENERATOR

FREQUENCY

VOLTAGE REGULATION

TEMPERATURE RISE

EXCITER CRANKING

WIRING DIAGRAM REPRESENTATION

FIELD DATA

TROUBLE ANALYSIS

The three basic types of Kohler generators have been discussed in previous papers. Our purpose here is to expand and clarify some of the points brought up in these discussions.

FREQUENCY

FREQUENCY OR CYCLES PER SECOND

Most Kohler A. C. generators are made for 60 cycle service. A few are made at 50 cycle for foreign use and a few rotating armature machines in 2.5 KW capacity for 180 cycle vibrator equipment. A definite relationship exists between cycles, speed, and number of poles. This relationship can be shown in its simplest form by the following formula:

FREQUENCY = REVOLUTIONS PER SECOND x PAIRS OF POLES

Frequency is always stated in cycles per second. A 60 cycle machine for example means that the A. C. wave makes 60 complete cycles each second. Speed is usually given in revolutions per minute or, for example, 1800 RPM. To fit into the above formula speed must be changed to revolutions per second. A simple example will show how the formula can be used. If a tachometer registers 1800 RPM when placed on the end of the generator shaft, we divide 1800/60 to find rev. per sec. and place the 30 rev. per sec. in the formula. We find 4 poles on the generator, or 2 pairs of poles, so we also place the 2 in the formula. The result is 30 x 2 or a frequency of 60 cycles per second.

The chart shows some common relationships between RPM and frequency.

Frequency	60	50	180
Poles	6	6	6
RPM	1200	1000	3600
Poles	4	4	
RPM	1800	1500	
Poles	2	2	
RPM	3600	3000	

VOLTAGE REGULATION

The term "voltage regulation" has a definite mathematical definition.

$$\text{Voltage regulation} = \frac{\text{No load voltage minus full load voltage}}{\text{Full load voltage}}$$

Let us calculate the voltage regulation for our model 1A21. This model has a no load voltage of 121 and a full load voltage of 115:

$$\text{Voltage regulation of 1A21} = \frac{\text{121 minus 115}}{115} = .05 = 5\%$$

Kohler A. C. plants use a number of means of obtaining good voltage regulation.

SATURATED POLE

The simplest and lowest cost means of obtaining good voltage regulation is the saturated pole generator. In this generator we simply use a very strong field winding. Thus when the demagnetizing effect of load current in the armature appears, its percentage effect is not very great. With this means the voltage must always go down with load. Such generators have a voltage regulation of about ten per cent at unity power factor.

ONE-STEP FIELD RELAY

The one KW generator uses a relay (s) with a contact in the field circuit which closes at about half load. This relay shorts out a resistor in the field circuit and thus increases the field current sufficiently to return the output voltage to approximately no load value. This generator has an overall regulation of about five per cent. The voltage regulation curve has a step in it as you can see by looking at the curve on the back of the 1000 watt A. C. specification sheet.

VOLTAGE STABILIZER

The voltage stabilizer type machine is used on 3.5 to 15 KW generators. This machine has auxiliary field windings. We insert a current transformer in the line to change the A. C. load current to a lower value and then rectify it to change it to D. C. This D. C. current is then passed into the auxiliary field. Current in this field then varies directly with line current. We cannot call it a voltage regulator because it senses current and not voltage. There is a real advantage however in responding to line current. This makes the response practically instantaneous. When a motor is started the voltage has no opportunity to drop as the increased field current is applied immediately. Regulation obtained by this means is about five per cent depending upon power factor. The disadvantages of the voltage stabilizer are that it is affected by speed droop and power factor.

The revolving field generators have the exciter separate from the alternator and use Regohm regulators or static regulators. They are true voltage regulators and sense A. C. voltage.

REGOHM REGULATOR

The Regohm regulator has a relay type A. C. coil which senses A. C. voltage. The desired control of field current is obtained by a set of multiple finger contacts which add or remove resistors from the exciter field circuit. The exciter field voltage is obtained from the exciter armature for this type of regulator. The response obtained by this method is not as fast as from the voltage stabilizer but the overall voltage regulation is better, about four per cent.

The Regohm is not affected by a speed droop or power factor to any great extent.

CURRENT FEEDBACK

Current feedback is available in conjunction with the Regohm regulator. This greatly improves the motor starting ability of a generator by rectifying some of the A. C. current and sending it into the exciter field. At the instant of starting a motor this current is very high which is just what is needed for fast response.

STATIC REGULATOR

The static voltage regulator also senses A. C. voltage. It is called "static" since it has no moving parts. The desired control of the field current is obtained by a saturable reactor or a silicon controlled rectifier (SCR). The exciter field voltage is obtained from the alternator output when this type of regulator is used.

The response obtained by this method is fast and is not affected by speed droop or power factor to any great extent. There are no mechanical problems since it has no moving parts. The regulation is four per cent.

TEMPERATURE RISE

A. C. and D. C. generators are usually designed and rated at the load which they can safely carry without overheating. If the temperature of the generator becomes too high due to overloading or high room temperatures, the insulation on the armature and field conductors and the insulating varnish deteriorate.

CLASS A INSULATION

Materials for class A insulations used in our machines include cotton, enamel, rag paper, fibre, and varnish. Safe temperature standards for class A insulation indicate a limit of 105°C. This figure includes a 50°C. rise using a thermometer, a 40°C. ambient temperature, and a 15° allowance for the hottest spot temperature.

If temperature rise is measured by resistance, a 60°C. rise is allowed at a 40°C. ambient and 5° allowance which again totals 105°C. Tests indicate that the minimum life of generators with class A insulation, running at a temperature of 100°C. is roughly 14 years. If temperature was increased to 125°C. the minimum expected life would drop to about 2 years, or only 14% of the expected total life of the generator.

EXCITER CRANKING

In an exciter cranked plant the engine is cranked for starting by the direct connected exciter armature. The generator becomes a series motor during the starting cycle by adding a cranking field to the system. Included in a typical cranking circuit is the cranking relay contacts, the cranking series field coils, the brushes, the exciter armature winding, and the leads and terminal connections.

TORQUE

The amount of torque developed by the armature to turn the engine shaft depends on the number of lines of force in the field times conductors on armature times armature current times number of poles divided by the paths through the armature.

In any armature, the winding and number of poles is fixed so the torque then depends on only two factors which are the number of lines of force and the current. Since the same current flows in the field as in the armature, the cranking current must be as high as practical in relation to capacity of battery and circuit.

The battery used for cranking needs an ampere hour capacity large enough to supply the required cranking current without an excessive voltage drop. The battery must also continue to

AMPERE HOUR CAPACITY

crank the plant long enough to assure engine starting. If the battery voltage continues to drop during the two or three minute cranking period, the AH capacity is probably too small. It may reach the point where it can no longer supply the required current, so the engine stops, even though current is flowing through the cranking circuit. This condition causes excessive heating of generator parts, and is harmful to the battery. The battery should be kept fully charged.

Resistance of the cranking circuit must be held to a minimum, since an increase of resistance in any part of the circuit will lower the cranking current and decrease the torque. Because of the high current flowing, all terminal connections must be tight to prevent local heating of connections.

Battery leads must be of the proper size and the battery should be close to plant so short battery leads can be used.

Connections of brush pigtails and proper seating of brushes is also necessary. The full effectiveness of the battery will be lost if there is an excessive voltage drop in the circuit between the battery and the generator windings.

VOLTAGES

Battery voltages used on exciter cranked plants range from 12 volts on small plants to 36 volts on the large plants. The initial torque required to crank an engine can result in momentary current to 600 ampere on larger plants. Cranking speed will range from 200 RPM on the large plants to 1200 RPM on the small plants.

WIRING DIAGRAM REPRESENTATION

In our wiring diagrams we use a simplified representation of the parts of the generator. A typical wiring diagram is shown in Figure 4.2. Area "A" indicates the D. C. components of the generator while area "B" indicates the A. C. components. Let us examine these more closely.

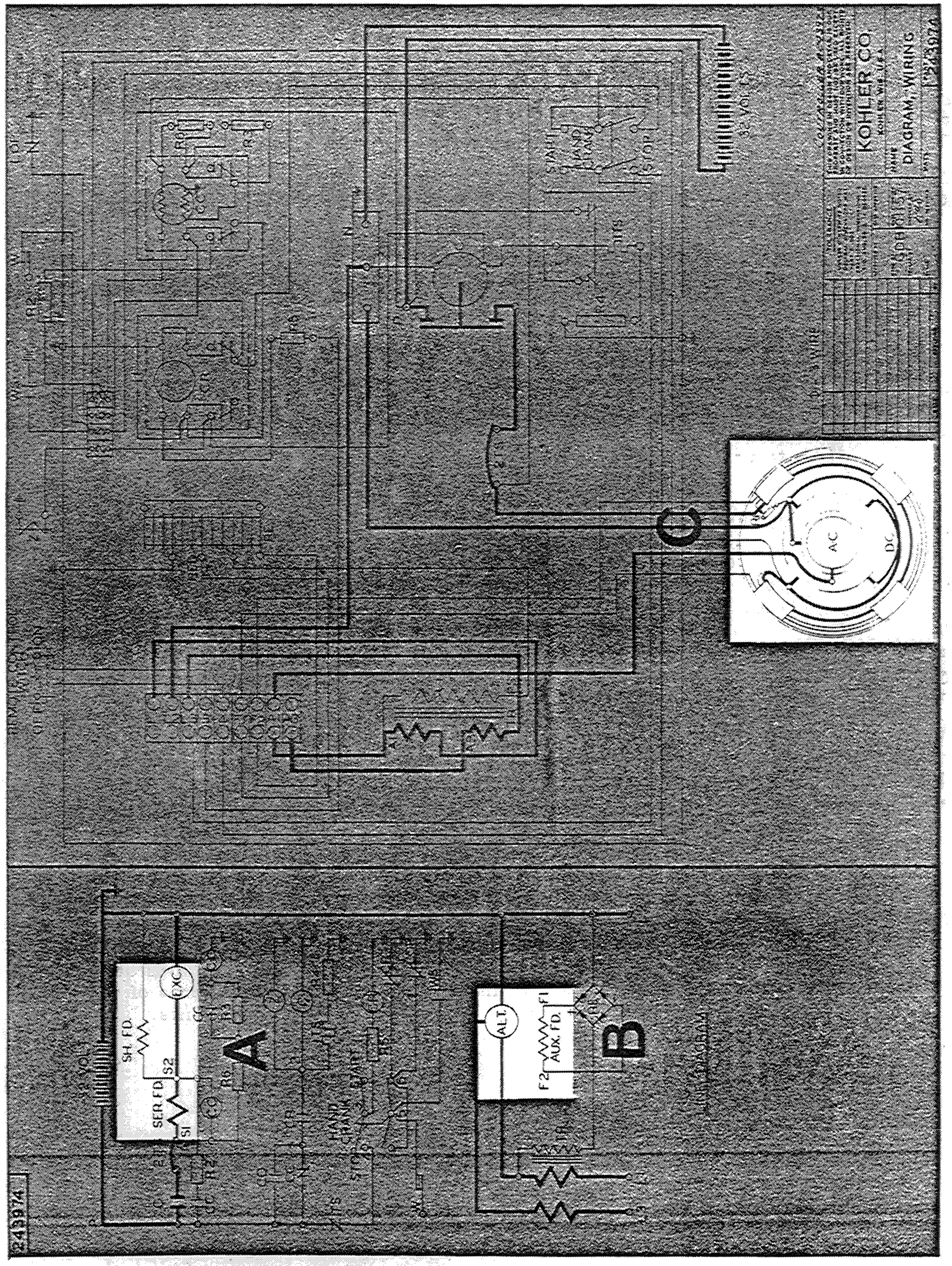

249974
32 VOLT
SH. FD.
SER. FD.
S1
S2
EXC
A
HAND CRANK
START
STOP
ALT.
AUX. FD.
F1
F2
B
C
AC
DC
32 VOLTS
HAND CRANK
START
STOP
KOHLER CO.
KOHLER, WIS. U.S.A.
DIAGRAM, WIRING
249974

Figure 4.2

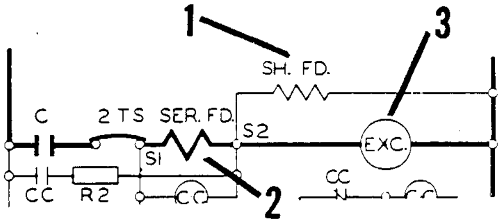


Figure 4. 3

AREA "A"

The three D.C. generator components are shown in area "A". They are:

1. The shunt field coil winding.
2. The cranking series coil winding.
3. The armature exciter winding.

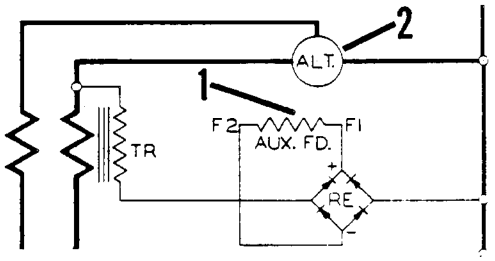


Figure 4. 4

AREA "B"

The A. C. generator components are shown in area "B". They are:

1. The auxiliary field coil winding.
2. The A. C. armature winding.

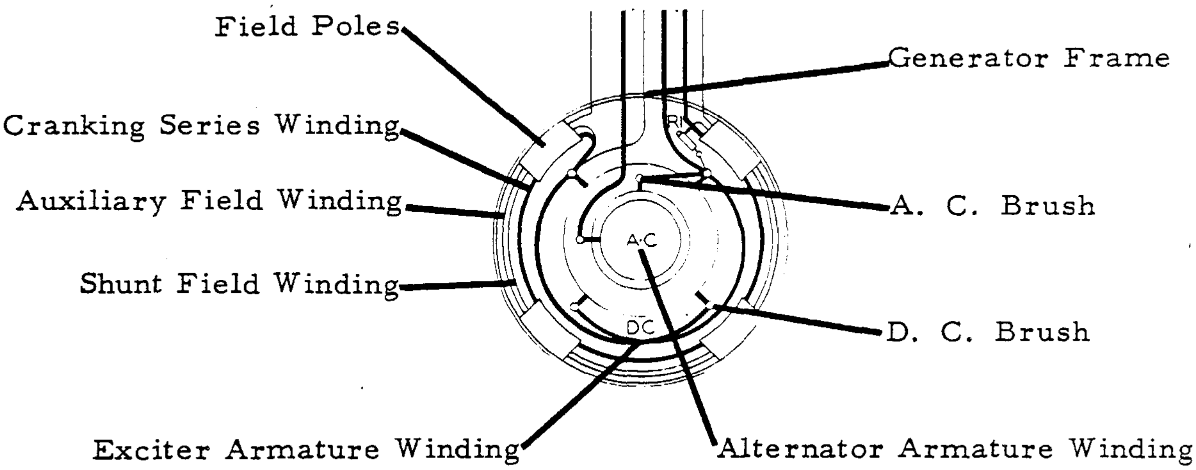


Figure 4.5

AREA "C"

The generator representation on the schematic portion of the wiring diagram is shown in Figure 4.5. The various components are called out in the illustration.

The representations shown here are standard on all Kohler Co. wiring diagrams.

FIELD DATA FOR AC GENERATORS
An Aid to Trouble Shooting
Rotating Armature Generators

Plant	Shunt Field Resistance		Auxiliary Field Resistance (ohms)		Exciter	Auxiliary Field Volts	
	Cold	Hot	Cold	Hot	Volts	No Load	Full Load
500 W - K91	1.1	1.4			13		
750 W - K91	0.8	1.0			14		
1250 W - K161	1.8	2.2			20		
1500 W - K91	3.8	4.8			26		
3000 W - K161	2.3	2.8			19		
2500 W (Marine)	2.5	3			24		
3000 W 240 V 180 Cycle	56	69			115		
3000 W 120 V 180 Cycle	56	69			115		
3.5 KW - K301	3	3.5			35		
2.5 KW - L600 & K241	3	3.6			30		
4 KW 1 Ph. - K331	3	3.7			28	6	50
4 KW 3 Ph. - K331	4.5	5.4	100	120	28	15	50
5 KW - 6.5 KW 1 Ph.	4.2	5.3	26	31	30	3	40
5 KW - 6.5 KW 3 Ph.	4.2	5.3	38	47	30	2	70
7.5 KW 1 Ph.	4.2	5.6	18	23	36	3	52
7.5 KW 3 Ph.	4.7	5.3	38	47	30	2	70
7.5 KW 1 Ph. Marine Diesel	3.8	4.7			42		
12.5 KW 1 Ph.) Liquid	6.5	7.5	29	35	63	3	65
12.5 KW 3 Ph.) Cooled	6.5	7.5	40	52	55	10	80
10 KW 1 Ph.	8	10	20	25	39	2	46
10 KW 3 Ph.	13	15	41	49	36	2 11	60 (208V) 73 (240V)
15 KW 1 Ph.	5.3	6.4	13	17	45	3	40
15 KW 3 Ph.	5.3	6.4	56	68	45	12	85

NOTE: TO CHECK THE FOLLOWING CIRCUITS -

1. Shunt Field Resistance - Open shunt field circuit at resistor and measure resistance across F and + brush.
2. Auxiliary Field Resistance - Open auxiliary field circuit at F1 and measure resistance across field wires F1 and F2.
3. Exciter Volts - Connect DC voltmeter across top exciter brush terminals.
4. Auxiliary Field Volts - Connect DC voltmeter across terminals F1 and F2.

FIELD DATA FOR AC GENERATORS WITH STATIC REGULATOR

An Aid to Trouble Shooting
Revolving Field Generators

Generator	Exciter Field Resistance		Rotor Resistance		Exciter Volts	
Exciter Cranking	Cold	Hot	Cold	Hot	No Load	Full Load
25 to 30 KW, 4 pole	12	13	8.5	10	17	90
35 to 45 KW, 4 pole	12	13	7.3	8.2	17	90
50 to 55 KW, 4 pole	12	13	5.5	7.5	17	90
75 to 85 KW, 4 pole	13.5	14.5	5.3	6.6	15	90
15 KW, 6 pole	13.5	14.5	5.7	6.5	19	90
25 to 30 KW, 6 pole	13.5	14.5	6.9	8.6	21	90
35 KW, 6 pole	13.5	14.5	6.2	7.3	21	90
25 to 30 KW, 4 pole, (Diesel)	13.5	14.5	8.5	10	17	90
35 to 45 KW, 4 pole, (Diesel)	13.5	14.5	7.3	8.2	17	90
100 to 115 KW, 4 pole	10	11	3.2	4.2	17	90
125 to 170 KW, 4 pole	10	11	2.7	3.5	15	90
Automotive Cranking						
75 to 85 KW, 4 pole	12	13	5.3	6.6	15	90
100 to 115 KW, 4 pole	11.5	12.5	3.2	4.2	17	90
125 to 170 KW, 4 pole	12.5	13.5	2.7	3.5	15	90

NOTE: TO CHECK THE FOLLOWING CIRCUITS -

1. Exciter Field Resistance - Open exciter field circuit at F1 and measure resistance across F1 and F leads.
2. Rotor Resistance - Lift brushes off one collector ring and measure resistance across collector ring.
3. Exciter Volts - Connect DC voltmeter across top exciter brush terminals.

ROTATING ARMATURE GENERATORS TROUBLE ANALYSIS

SYMPTOM	CHECK	POSSIBLE FAULT
A. No exciter voltage No. A.C. voltage	1. Check for open shunt field circuit	Open field resistor Broken connection between field resistor and negative brush, or between coils. Brushes not seated on commutator. Dirty commutator. Loose terminal connection at brushes.
	2. Lift brushes off commutator and:	
	a. Check armature for ground.	Grounded D. C. armature.
	b. Remove shunt field Lead from field resistor and check field for ground.	Grounded field
	c. On plants without field resistor check for ground after disconnecting field at negative brush.	
	d. Manual plants may require "Flashing" to restore residual magnetism. Lift brushes off commutator connect plus battery to plus generator terminal.	No residual magnetism.

	Touch negative battery to negative generator terminal momentarily to restore residual magnetism.	
B. Low voltage at no load	1. Check engine speed.	Low speed.
	2. Check total resistance of field coils.	Field coil shorted out of field circuit (will indicate low voltage only on plants with field resistor).
	3. Check for resistor with too high resistance in field circuit.	Wrong resistor
	4. Short out resistor to check if voltage will rise.	
C. Exciter voltage No A. C. voltage	1. Check for open A. C. lead.	Open A. C. lead
	2. Check for brushes too tight or worn too short.	A. C. brushes not riding on collector rings.
	3. Lift A. C. brushes and check for open circuit of A. C. armature.	Open circuit of A. C. armature.
	4. Engine will labor. Check for hot armature. Plant will crank in jerks.	Short circuit of A. C. armature or line.
D. Excess voltage drop under load	1. On generators with voltage stabilizer check for reversed battery connection.	Wrong polarity.
	2. Check for reversed auxiliary field.	Wrong polarity (F1 should be positive on plants with negative ground).

	3. Check resistance of auxiliary field. (Remove F1 terminal and check resistance across F1 and F2 field leads.)	Shorted or open auxiliary field.
	4. Check engine speed under load.	Insufficient engine power.
	5. Open both terminals of auxiliary field and check for short between auxiliary field and generator. Auxiliary field should be insulated from generator and not grounded.	Short between auxiliary field and generator.
E. Brush arcing	1. Check position and condition of brushes.	Brushes not seated. Brushes sticking in holder. Improper position of brush springs causing uneven brush wear. Brushes worn too short.
	2. Check part number of brushes.	Wrong brush material.

Brush Maintenance:

1. On generators without interpoles, shift brushes to position of least arcing at about 3/4 load.
2. Brushes of generators with interpoles must be on the no load neutral position. Usually in line with field pole bolts.
3. Periodic checking and cleaning of commutator and brushes is required for continued good performance.
4. Clean commutator with fine sandpaper (not emery paper) or commutator stone.

REVOLVING FIELD GENERATORS
TROUBLE ANALYSIS

SYMPTOM	CHECK	POSSIBLE FAULT
A. No build-up of voltage	1. Check for open exciter field circuit.	Broken wire or connection in exciter field circuit. Defective regohm (Short out A to B). Brushes not seated on commutator. Dirty commutator. Loose terminal connection at brushes.
	2. Lift brushes off commutator and:	
	a. Check armature for ground.	Grounded D. C. armature
	b. Automotive cranked Plants may require "Flashing" to restore residual magnetism. Disconnect F1. Momentarily touch plus battery to F lead and negative battery to F1.	No residual magnetism.
B. Exciter voltage No A. C. voltage	1. Check for brushes too tight or worn too short.	A. C. brushes not riding on collector rings.
	2. Check for D. C. voltage across collector ring brushes.	Open leads between exciter brushes and collector rings.

	3. Check for open circuit of rotor by lifting brushes off collector ring and checking resistance across collector rings.	Open circuit of rotor. Any break in alternator field circuit will result in high exciter voltage.
	4. Check continuity across phases of stator for open circuit if no voltage on one or all phases.	Open circuit of stator.
	5. Check for hot stator windings.	Short circuit of A. C. stator windings or load line.
C. High A. C. voltage High exciter voltage	1. Check A. C. regohm circuit.	Open circuit between terminals 2 and 9 (Includes regulator, rheostat and terminals C and D of regulator).
	2. Check D. C. regohm circuit.	Regohm plug-in unit defective. Remove plug-in unit to check if voltage will drop to low valve.
D. Brush arcing	1. Check position and condition of brushes.	Brushes not seated. Brushes sticking in holder. Improper position of brush springs causing uneven brush wear. Brushes worn too short.
	2. Check part number of brushes.	Wrong brush material.

Brush Maintenance:

1. On generators without interpoles, shift brushes to position of least arcing at about 3/4 load.
2. Brushes of generators with interpoles must be on the no load neutral position. Usually in line with field pole bolts.
3. Periodic checking and cleaning of commutator and brushes is required for continued good performance.
4. Clean commutator with fine sandpaper (not emery paper) or commutator stone.

ES 492 2M B Class IV **Printed in U.S.A.**

T I Series No. GE-

TECHNICAL INFORMATION

STATIC VOLTAGE REGULATORS

KOHLER CO. of KOHLER, WIS. 53044

Introduction

The information in this publication is offered as an introduction to the basic theory of operation and requirements of the solid state, static voltage regulators used on specific models of Kohler Generator Sets. A basic knowledge of electronics is helpful to understanding the theory of operation as described for each of the three general types of static regulators covered in this manual. While these static regulators are essentially non-serviceable, a better understanding of their function could be helpful in pinpointing possible malfunctions which could be attributed to the regulator. Trouble analysis guides are provided for this purpose.

CONTENTS

STATIC VOLTAGE REGULATORS

A voltage regulator functions to control or maintain output voltage of a generator set at a constant level regardless of changing load conditions. Without proper regulation, output voltage would tend to decrease as the load increases and increase as load is removed. The life of light bulbs would, for example, be cut in half by as little as 5% overvoltage condition while performance of all electrical equipment is adversely affected by undervoltage conditions.

Two factors influence output voltage. Frequency is directly related to engine speed which is controlled by the governor on the engine. Magnitude of the voltage is related to field excitation of the generator. Any increase in field excitation brings about a corresponding increase in output voltage while decrease in excitation results in a decrease in output voltage. Just as a governor reacts to restore engine speed when a heavy load is applied, a voltage regulator reacts to increase field excitation and thus restore output voltage to rated value.

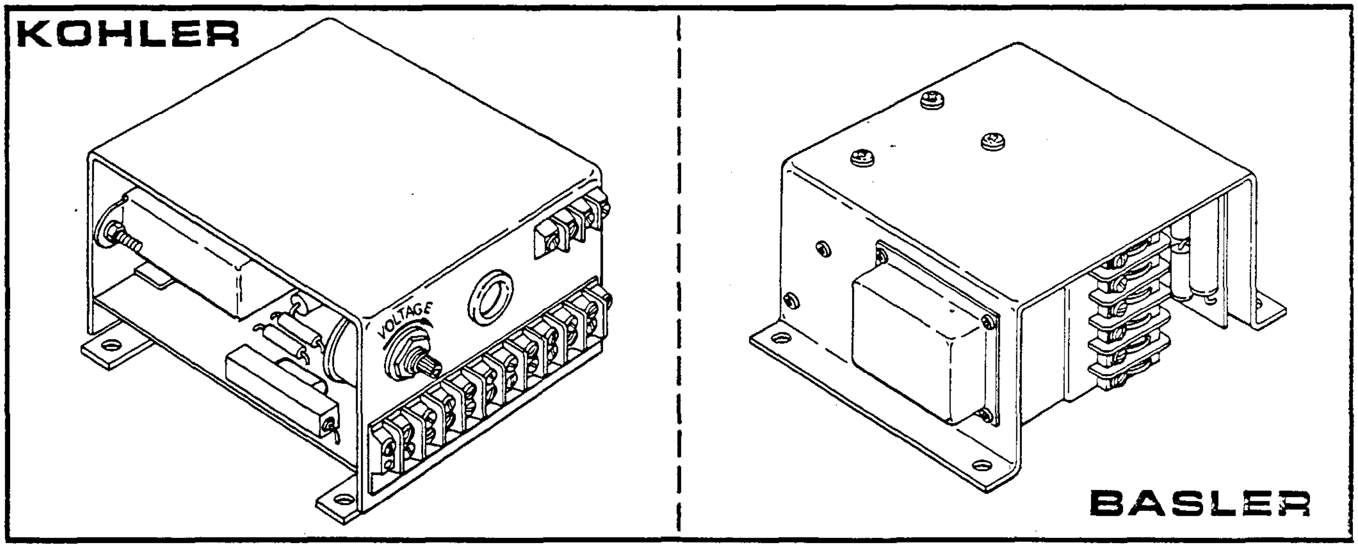


FIGURE 1 -- KOHLER & BASLER STATIC VOLTAGE REGULATORS

Static voltage regulators control excitation through the use of solid state electronic devices. Solid state or static denotes that the regulator has no moving parts. Without any moving parts such as electromechanical contacts, the static regulator is capable of faster response, is not subject to wear and is not generally affected by vibration. Another advantage of a static regulator is that its function is relatively unaffected by temperature changes and temperature extremes.

At present two different makes of static regulators are used on Kohler Generator Sets. They are manufactured by Kohler Co. and by Basler Electric Company. The Kohler static regulator models, with two exceptions, are used with Kohler static exciter generators. Two Kohler static regulator models are used with revolving field generators which employ rotating DC exciters. The Basler static regulators are used almost exclusively on Kohler revolving field generators. The static regulators are normally mounted inside the controller. Part numbers (model number on Basler regulators) are printed on the cover of the static regulators. The static regulators and where they are used are listed in the chart below.

REGULATOR MANUFACTURER	KOHLER PART NO.	LIMITING FACTORS		PHASE
		KW SIZE	GENERATOR TYPE	
Kohler	A-269000	10-30	Rotating Exciter: 12 & 24 volt	Single or three
Kohler	A-269766	10-30	Rotating Exciter: 32 & 36 volt	Single or three
Kohler	B-269659	10-230	Static Exciter	Single
Kohler	B-269735	10-30	Static Exciter	Three
Kohler	B-269602	45-230	Static Exciter	Three
Basler-KT3B	A-284498	45-85	Rotating Exciter (Exciter Cranked)	Single or three
Basler-KT3	A-284499	45-85	Rotating Exciter (Automotive cranking)	Single or three

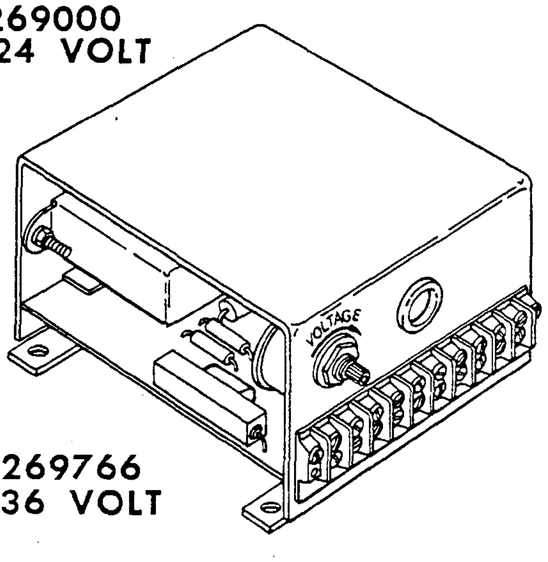
Since the static regulators use solid state electronic devices and printed circuits, complicated repairs should be made only by the manufacturer. A spare regulator should be stocked to prevent downtime in the event the original requires repair. While field repairs are not recommended, the principle of operation of the regulators are discussed in the following--this information may help determine if the regulator is actually at fault when problems arise.

KOHLER STATIC REGULATORS-ROTATING EXCITER SETS

The static regulators shown below are used on 10 to 30 KW generator sets with revolving field - rotating exciter generators. The principle of operation of these regulators is as follows. Refer to the schematic diagram at the top of the opposite page to trace the sequence of operation.

Voltage Regulation: Alternator voltage build-up begins after the machine begins to rotate and battery voltage is applied to terminal 3. At this time, the transistors, Q2 and Q3, conduct current because of the current flowing from the battery through resistor R11. This allows current to flow from the battery through resistor R10 and the base of transistor Q4, turning this transistor "on". There is now a path for field current flow from terminal 3, through Q4 into the field, by means of terminals 9 and 4, and then to ground through transistor Q3 and diode CR3.

A-269000
12-24 VOLT



A-269766
32-36 VOLT

CHARACTERISTICS

REGULATED VOLTAGE	
Voltage	120/208/240
Frequency	50-60 CPS
Phases Sensed	1
REGULATOR OUTPUT POWER	
Maximum Voltage (A-269000)	22
Maximum Voltage (A-269766)	30-34
Max Continuous Current	3 Amps
Max Current for 2 Minutes	6 Amps
REGULATOR INPUT POWER	
Battery Source (A-269000)	12-24 V
Battery Source (A-269766)	32-36 V
Current Required (Continuous)	3 Amps
VOLTAGE ADJUSTMENT	
Range (Minimum)	± 10%

REGULATION

Regulator output voltage goes from maximum to minimum (essentially zero) when sensed voltage is increased by 2% above the preset value.

AMBIENT OPERATING TEMPERATURE

Range - Centigrade -30° to +71°C

FIGURE 2--Kohler Regulators for Rotating Exciter Generators

The alternator voltage is applied to terminals 5 and 6 for 120 volts and terminals 5 and 7 for 208/240 volts. This voltage is decreased by the isolation transformer T1, rectified by CR8 and filtered by R1, C1, R2 and C2. Resistors R3, R4 and R14 provide a further decrease in voltage and means for adjustment. The resulting DC voltage is then compared to a constant reference voltage produced by the action of zener diode CR7, resistor R5 and capacitor C3. The resulting error voltage is used to control transistor Q1.

When the regulated voltage gets above the preset value, this error voltage becomes positive; causing Q1 to turn "on". This shorts the current flowing through R11 to ground causing transistors Q2, O3, and Q4 to turn "off".

When the power transistors Q3 and Q4 turn "off", the field current must continue to flow in the high inductive field if high induced voltages are to be avoided. An alternate current path is provided through diodes CR2 and CR5. The field current flows from terminal 4 through CR2 into the positive terminal of the battery and then to ground. To complete its circuit, the current then flows from ground through diode CR5 into terminal 9 and then through the field to terminal 4 again. A comparison of this current flow to that occurring when the transistors were "on" will show that the field voltage reversed in polarity. When the transistors were "on", the positive terminal of the battery was connected to the positive side of the field. When the transistors are "off", the negative battery terminal is connected to the positive side of the field. The occurrence of a positive field voltage when the alternator voltage is less than the present value and a negative field voltage when it is greater, results in regulation of the alternator voltage as required.

Stabilizing Circuit: Because of the number of large time constants within the machine, a feedback signal is necessary to prevent an unstable system. This signal is obtained from the exciter output voltage, applied at terminal 8, through the action of resistors R12 and R13 and capacitors C5 and C6.

Negative Forcing Characteristic: The application of negative voltage to the field when the alternator voltage is high, as described previously, is commonly called "negative forcing". Negative forcing is desirable, as compared to regulators providing only positive to zero field voltages; because it provides a more rapid recovery from transients, such as an abrupt load removal from the alternator.

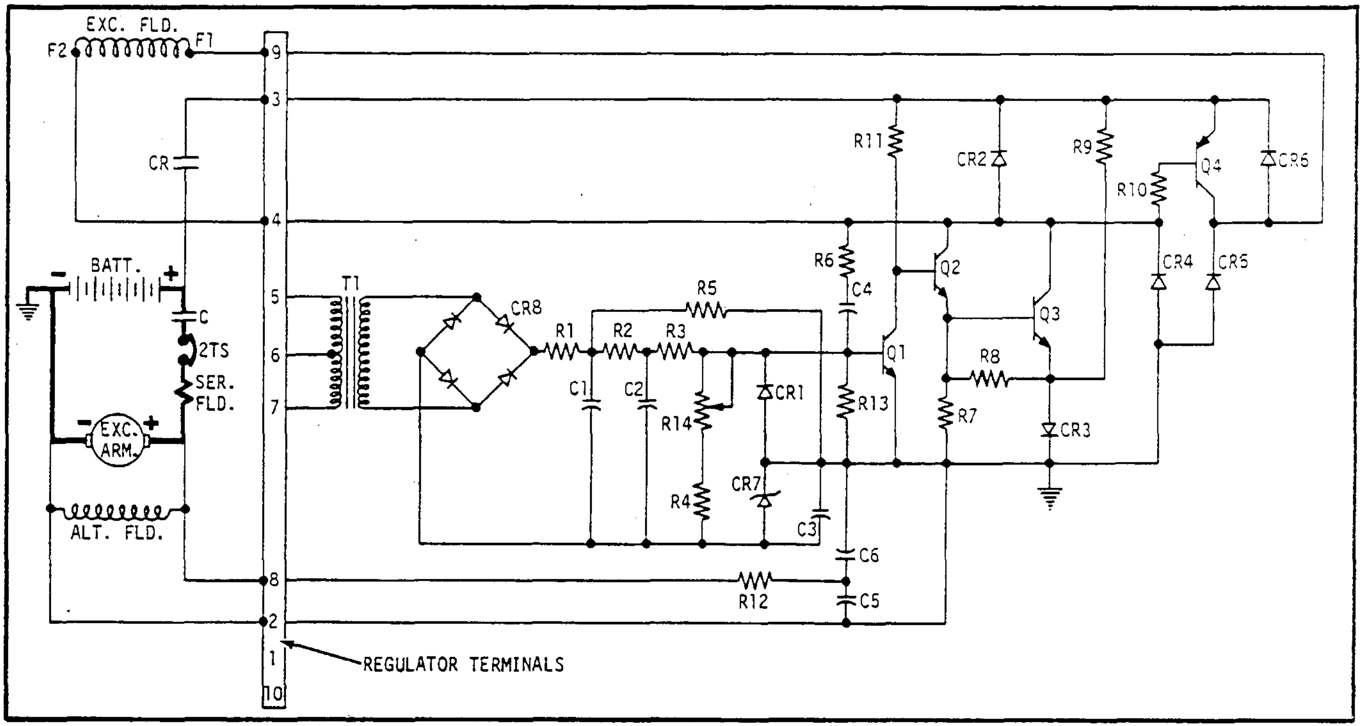


FIGURE 3--Schematic Diagram of Kohler A-269000 & A-269766 regulators

INSTALLATION: The regulator may be mounted in any position without affecting its operation.

OPERATION PRECAUTIONS: The voltage regulator should be operated only at voltages, currents and frequencies specified.

Since this regulator obtains power from the battery, flashing should not be necessary. Unless the regulator is disconnected completely, it may be damaged if flashing is attempted.

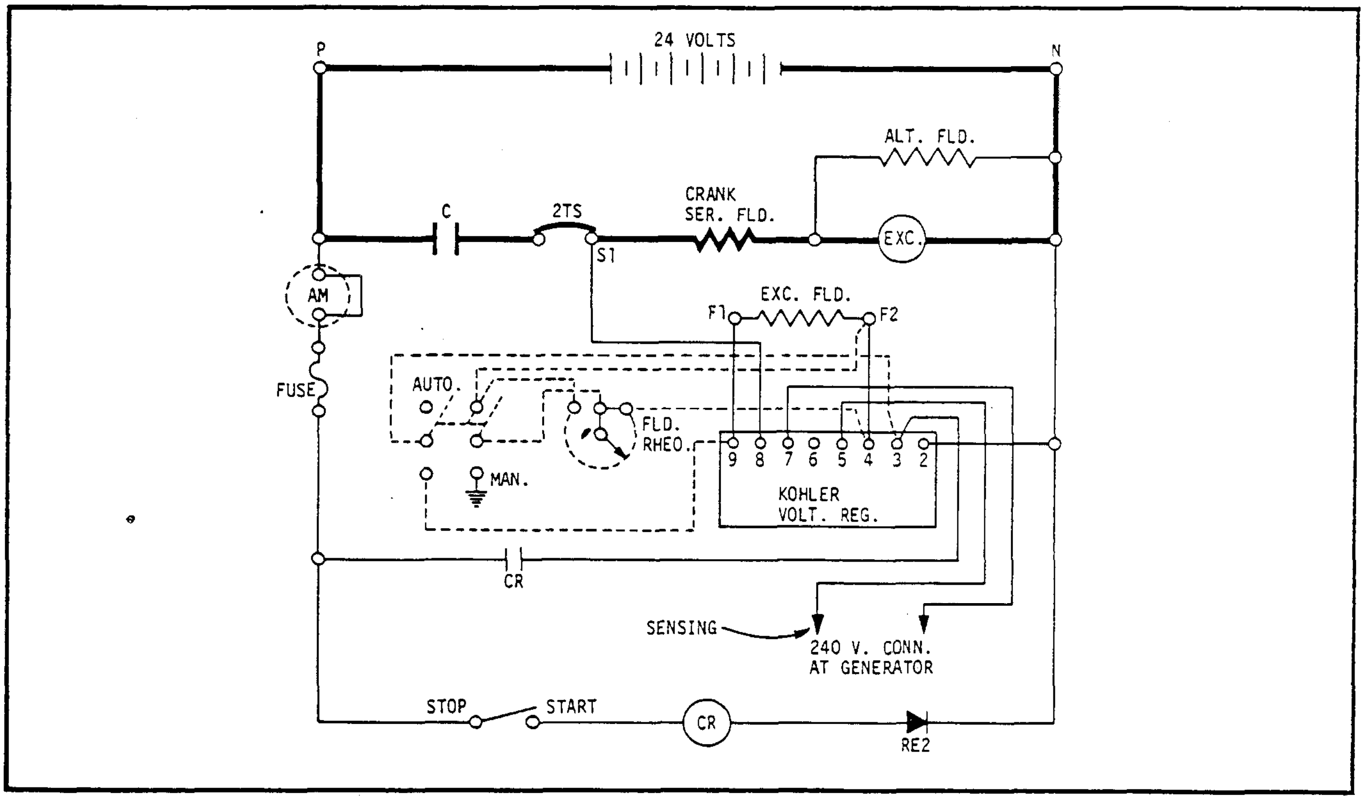


FIGURE 4--Connection diagram for Kohler A-269000 & A-269766 regulators

TROUBLE SHOOTING - A-269000 & A-269766 REGULATORS

SYMPTOM	PROBABLE CAUSE	REMEDY
No build-up.	●Open circuit between battery and field. ●Battery discharged.	●Make correct connections. ●Charge battery.
Generator output voltage goes to maximum value.	●Regulator sensing terminals not connected properly. ●Check terminals 5 and 6 (120 V. connection) or terminals 5 and 7 (240 V. connection).	●Correct connections.
Generator output erratic.	●Badly worn, dirty or improperly seated brushes. ●S1 to terminal B on regulator open ●Dirty commutator.	●Replace, clean or reseat brushes. ●Correct connections. ●Clean commutator.

ADJUSTMENT: A voltage adjustment potentiometer (R14) is provided for at least an adjustment of ± 10% of nominal voltage.

PREVENTIVE MAINTENANCE: Since the regulator is a solid-state type, it is not subject to wear or degradation and, therefore, requires no preventive maintenance under normal operating conditions.

CORRECTIVE MAINTENANCE: In case of apparent regulator malfunction, the connections between the regulator and generator should be examined for shorts. The trouble shooting chart lists some other possible troubles and corrective action.

CHARACTERISTICS - KOHLER STATIC REGULATORS & EXCITERS

GENERATORS	REGULATORS	EXCITERS
10 TO 30 KW	3 Phase - B-269735	3 Phase - A-283754 OR A-284451
45 TO 230 KW	3 Phase - B-269602	3 Phase - A-283754 OR A-284451
10 TO 230 KW	1 Phase - B-269659	1 Phase - A-283906 OR C-284452

APPLICATIONS

3 Phase Exciters -- Use on 3 phase WYE connected generators only.

Generator Voltages: 120/208 V., 3 phase, 4 wire; 240 V., 3 phase, 3 wire; 240/416 V., 3 phase, 4 wire; 277/480 V., 3 phase 4 wire; 600 V., 3 phase, 3 wire.

1 Phase Exciters -- Use on 3 phase DELTA and all 1 phase generators.

Generator Voltages: 120/240 V., 3 phase DELTA; 120 V., 3 phase DELTA; 120/240 V., 1 phase, 3 wire; 120 V., 1 phase, 2 wire.

Frequency -- 50 - 60 CPS.

REGULATOR SENSING (1 phase on all generators)

208 to 240 Volts (T2-T9) on 3 phase WYE connected generator.
240 Volts (T2-T9) on 3 phase DELTA or 120/240 Volts, 1 phase generator.
120 Volts (L1-L2) on 1 phase, 120 Volts, 2 wire generator.

MINIMUM VOLTAGE ADJUSTMENT ± 10% of nominal.

VOLTAGE REGULATION: 2% of Nominal

AMBIENT OPERATING TEMPERATURE -- -86° F. to +160°F.

KOHLER STATIC REGULATOR-STATIC EXCITER

The following describes the operation of the Kohler B-269602, B-269659 and B-269735 static voltage regulators which are used on generators with static excitation. The principle of operation of these regulators is as follows.

VOLTAGE REGULATION: Alternator output voltage is sensed by the static regulator. A fraction of this voltage is compared to a reference voltage across a zener diode. Any difference between sensed voltage and reference voltage is transferred to a pedestal circuit. The pedestal circuit utilizes the error to switch a unijunction transistor "on" at a precise angle of wavetime. The unijunction transistor sends signals simultaneously to the gates of all silicon controlled rectifiers in the exciter.

The S. C. R. with the highest anode voltage turns "on" and conducts current through the alternator field. It continues to conduct until another S. C. R. reaches a higher anode voltage. The regulator again sends signals to the gates of all S. C. R.'s and the second S. C. R. conducts current through the field. This sequence occurs three times during one generator cycle. The precise angle of wavetime when an S. C. R. turns "on" determines the amount of current it will conduct through the field.

The angle of wavetime is inversely proportional to the sensed output voltage. If the output voltage is low, the regulator sends signals sooner to the gates of the S. C. R.'s and they conduct for a longer period of time. The effect is more field current and higher output voltage. Likewise, if output voltage is high the regulator sends signals at a later angle of wavetime and the S. C. R.'s conduct for a shorter period of time.

Basic principles of operation are the same for three phase and single phase exciters and regulators. The three phase exciter utilizes three S. C. R.'s in a 3 or 4 wire, line to neutral, half wave connection. The single phase exciter uses four S. C. R.'s in a single phase, full wave bridge connection. Single phase static regulators are basically the same as 3 phase regulators. However, the regulators cannot be interchanged due to technical differences.

Generator output voltage is transformed and rectified by transformer T1 and rectifier CR1-CR4. A sensing circuit, primarily consisting of rheostat R2, transistor Q1 and reference diode CR5, detects any change in generator output requirements. The difference between sensed generator voltage and the reference voltage across zener diode CR5 is utilized to control a pedestal circuit.

The pedestal circuit determines the exact angle of wavetime that capacitor C3 becomes fully charged. When C3 is fully charged, a voltage potential is present across the emitter and base of unijunction transistor Q2. At exactly 12 volts Q2 is biased "on" and a pulse signal is sent to the gates of the silicon controlled rectifiers in the exciter. The S. C. R. with the highest anode voltage turns "on" and instantaneously conducts current through the field. It continues to conduct until another S. C. R. has a higher anode voltage.

VOLTAGE BUILD-UP: The alternator field is initially supplied with battery current as soon as starting switch is moved to "on" position. The battery continues to supply field current until stator generates enough voltage to actuate the static exciter. At this time, a relay in the controller disconnects the battery source of excitation.

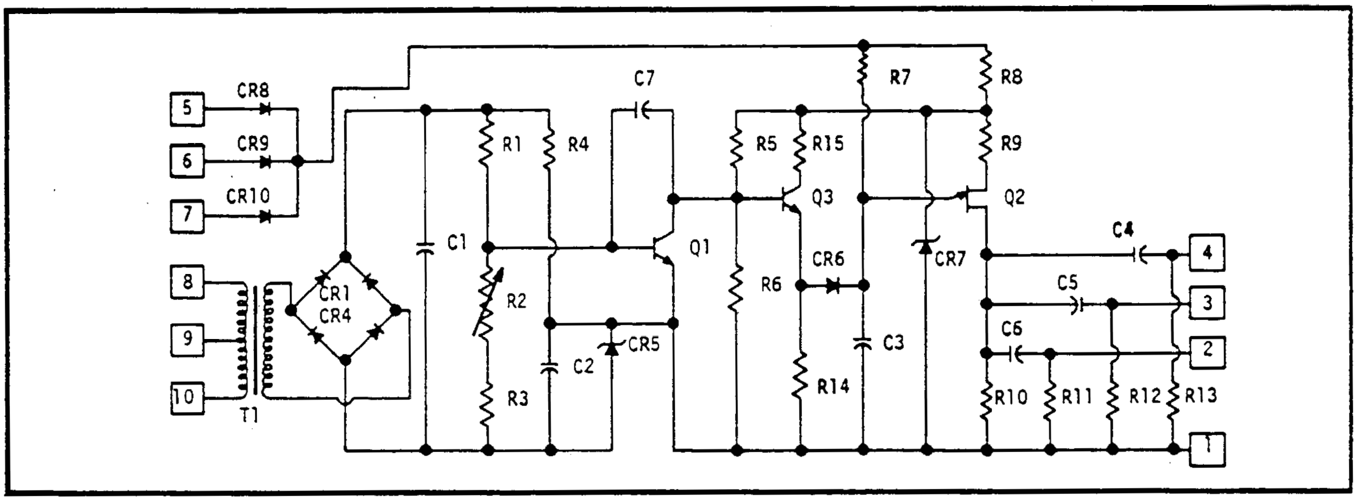


FIGURE 5--Schematic diagram of Kohler regulators used on static exciter generators

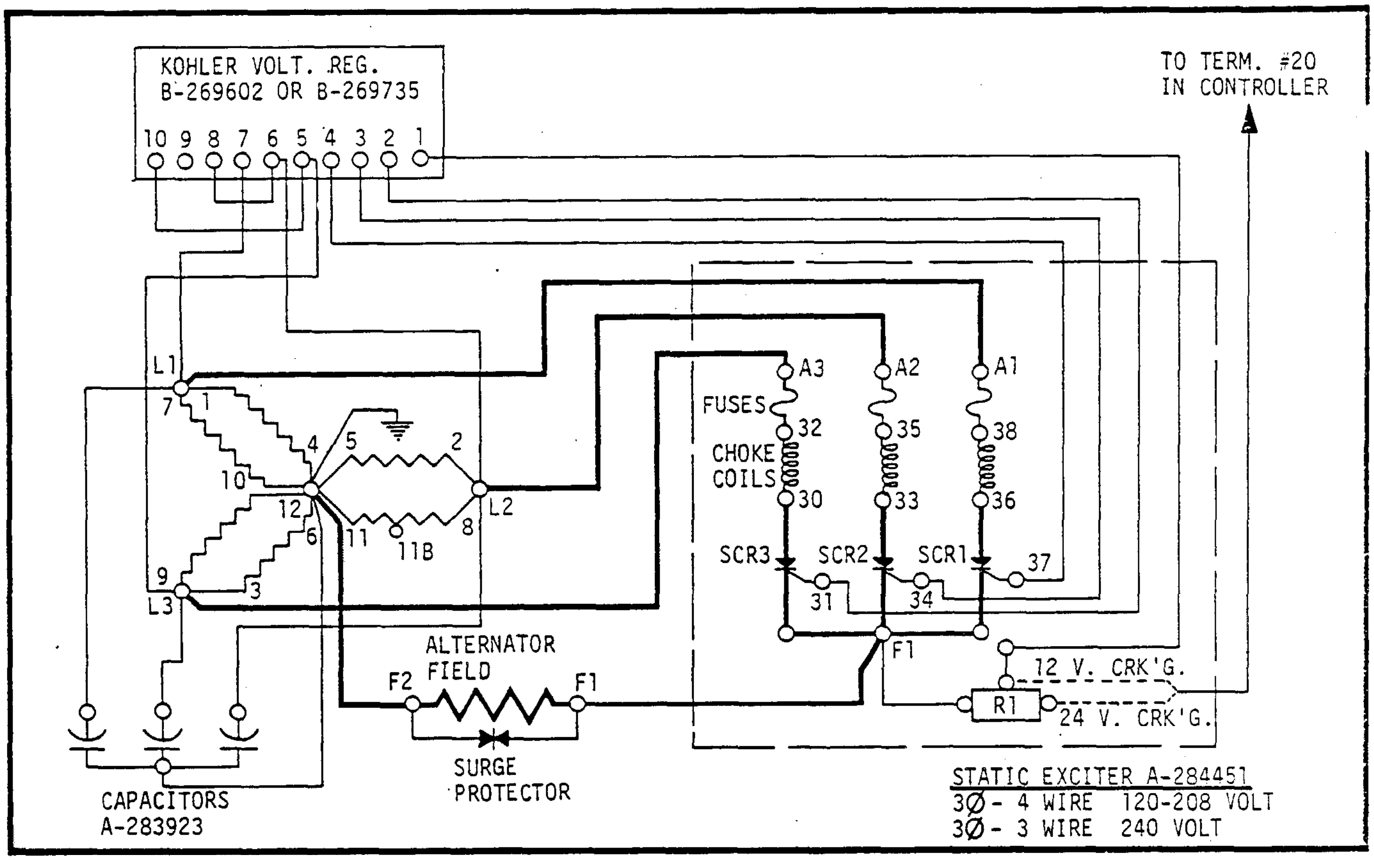


FIGURE 6--Typical wiring diagram for static exciter generator with static regulator

SURGE PROTECTION: During short circuits or sudden removal of a load, transient voltages could cause failure of S.C.R.'s if suitable protection is not provided. A surge protector is connected acros the alternator field and it effectively reduces the induced voltage to a safe value.

SUPPRESSION: Voltage distortion is controlled at the stator output terminals by three capacitors in the junction box. They are 2 microfarad, 400 volt capacitors. Conductive interference is controlled far below radio bands. Waveform distortion is reduced to a frequency of 5 to 25 kilocycles.

VOLTAGE ADJUSTMENT: A voltage adjusting rheostat is mounted on the regulator. No other adjustment is necessary. The rheostat has a minimum range of ± 10% nominal voltage. The regulator will provide ± 1% voltage regulation.

PREVENTATIVE MAINTENANCE: Since the static exciter and regulator are solid state, they are not subject to wear or degradation. However, they should be kept reasonably clean to avoid accumulation of deposits which may reduce cooling.

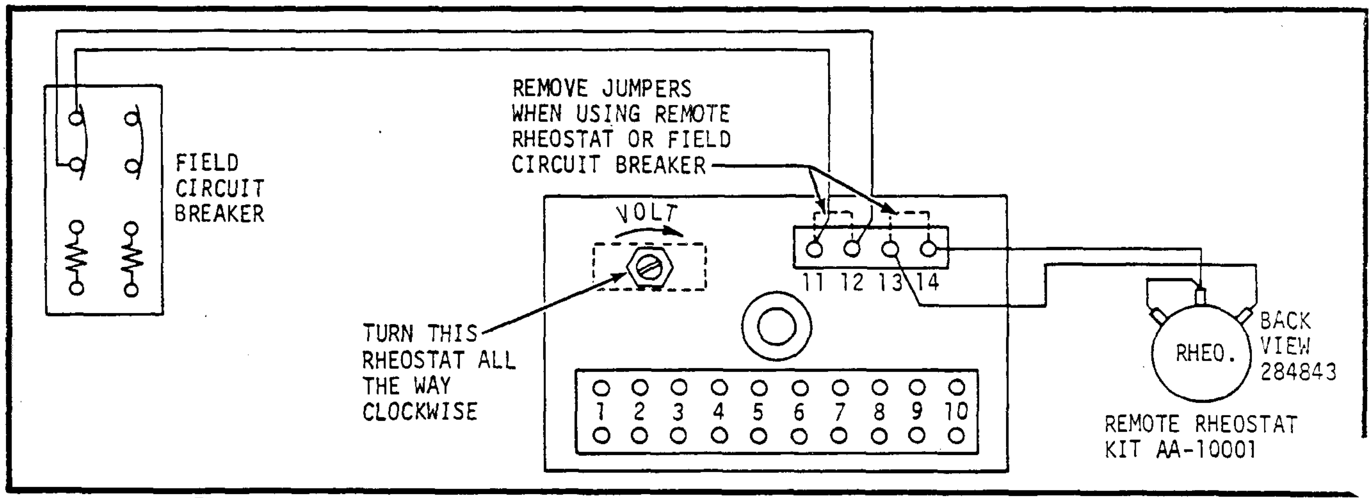


FIGURE 7--Connection of field circuit breaker and rheostat with Kohler static regulators

TROUBLE SHOOTING:STATIC EXCITER-STATIC REGULATOR

CONDITION	POSSIBLE CAUSE	ELIMINATION CHECKS
No Voltage	Build-up Circuitry	A - Controller fuse or field circuit breaker open. B - Exciter fuses open on single phase exciter. C - Connections loose or broken. D - Brush contact poor. E - Build-up relay contacts not closing in de-energized position. F - Exciter resistor R1 failed open. G - Shorted SCR's on three phase exciter (exciter fuses must be okay). Shorted SCR's 1 or 2 on single phase exciter. H - Rotor circuit open or grounded. I - Controller diode RE1 grounded or open. J - Shorted surge protector.
No Voltage	Short Circuit AC Output	A - Stator connected wrong (refer to Electric Plant Bulletin #397 or 421 for proper wiring). B - External wiring shorted. C - Circulating current high. D - Load ground not the same as generator ground.
Low Voltage	Regulator Malfunction	A - Loose connections. B - Incorrect wiring. C - Regulator defective. D - TEST: Hold build-up relay in de-energized position momentarily. If AC output voltage doesn't rise, the regulator is not at fault. If voltage rises to a high level, regulator is malfunctioning. (This test assumes that R11, R12 and R13 resistors in the regulator are operable.)
Low Voltage	Controller Faulty	TEST: Check voltage between terminal 20 and ground when starting switch is closed--12 or 24 volts should be present (dependent on starting battery voltage). If no voltage is observed, Controller is faulty. Check for improper wiring or faulty relays.
Low Voltage	Exciter Faulty	TEST: Approximately 4 volts or more DC should be present across collector rings during build-up. If less than this, exciter may be at fault. Check the following: 1. Fuse open. 2. SCR's shorted or open. 3. SCR's not switching - About 16 to 20 volts DC must be present across collector rings with plant running (no load) or else exciter may have SCR's which do not switch due to high gate requirements.
Low Voltage or No Voltage	Generator	A - Rotor may be grounded or partially shorted. Check rotor for proper resistance and no ground. Refer to Electric Plant Service Bulletins #397, 420 and 421. B - Stator ungrounded. C - Stator leads connected wrong.
High Voltage	Controller Faulty	A - TEST: Start plant and allow it to come up to speed, then immediately disconnect excitation lead at terminal 20. If voltage does not return to normal, trouble is in regulator or exciter. If it returns to normal, controller circuitry is at fault. B - AC relay not opening the build-up circuitry. (Some push button controllers use a DC relay for the build-up circuit with a rectifier. Relay fails due to rectifier failure.) C - Trace build-up circuitry thru controller as per controller diagram.
High Voltage	Regulator Faulty	A - Open regulator circuit breaker. If voltage recedes regulator is faulty, sensing circuit is open or regulator terminal 1 is not connected to proper exciter terminal 35 or R1. B - If plant has no circuit breaker remove jumper on regulator terminals A and B and replace with toggle switch to simulate circuit breaker. C - 208/240 volts should be obtained across regulator terminal 8 and 10 or sensing circuit wires are not properly connected to stator leads. D - Check for loose connections. E - Check rheostat setting.
Voltage Fluctuation	(See next column)	A - Defective regulator. B - Poor brush contact. C - Defective build-up relay. D - Loose capacitor connections. E - Loose electrical connections. F - Defective SCR.

BASLER STATIC REGULATORS-ROTATING EXCITER

The Basler static regulators as used on Kohler generator sets control current through the rotating exciter field to regulate output voltage. The principle of operation of the Basler Static regulator is as follows.

VOLTAGE REGULATION: The regulator acts as an automatic field rheostat which precisely controls the field current in order to maintain a constant output voltage of the generator. Initially current flowing through resistors R12 and R10 causes current to flow in transistors Q2, Q3, Q4, Q5 and Q6. The alternator voltage at terminals E1 and E3, in the sensing circuit, is stepped down, rectified and filtered to form a DC sensing signal. A fraction of this signal is compared to the voltage across reference diode VR1 to develop an error signal. When the alternator voltage becomes too high, the sensing circuit produces a positive error signal which is applied to the base of transistor Q1. This causes an increase in the collector current of Q1 and a corresponding decrease in the current through Q2, Q3, Q4, Q5 and Q6. To minimize power loss, the power transistors operate in a switching manner in variable turn-on duty cycles. Regulator sensing leads are E1 and E3. An internal sensing transformer (T1) has provisions for sensing 120, 208, 240, 416 or 480 volts AC. The transformer is normally connected to the 208 volt tap during manufacture and must be reconnected if other voltages are involved--transformer taps are illustrated in Figure 9.

The voltage regulator must be connected to the generator system exactly as indicated in the interconnection diagram. A thorough check and test should be made to determine that all connections are made to all terminals in the manner specified. An electrical test by an ohmmeter is the preferred method of checking for correct connections. Number 18 gauge wire or larger should be used to connect the voltage regulator

GENERAL: The voltage regulator should be operated only at voltages and frequencies specified for the equipment. The speed of the engine should be the normal operating speed corresponding to the normal output frequency of the generator. CAUTION: Operating generator set at reduced speeds (idle) will result in damage of this regulator.

FIELD FLASHING: On exciter cranked generator sets, battery voltage is applied to the exciter field thru the cranking windings during cranking. On automotive cranked sets (starting motor) initial build-up is supplied by battery voltage from the starter solenoid thru a diode and resistor to the field. NOTE: External field flashing is not necessary with this regulator.

INSTALLATION: A free convection flow of cooling air must be allowed to circulate through the unit. The unit should not be mounted near other heat generating equipment or mounted inside totally enclosed switchboards without ducts to outside cooling air. The regulator can be mounted in any position without affecting its regulating characteristics. To obtain maximum cooling, make sure the open ends of the regulator are vertical when mounted.

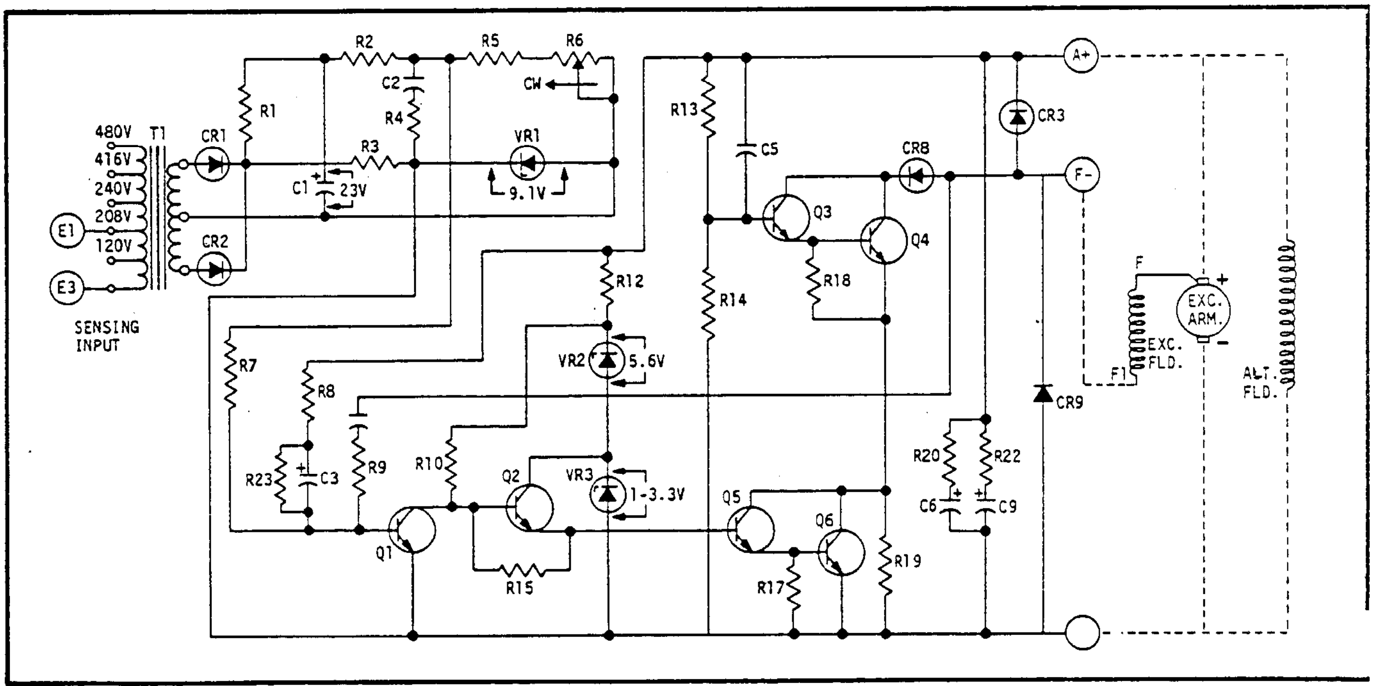


FIGURE 8--Schematic diagram of Basler static voltage regulators

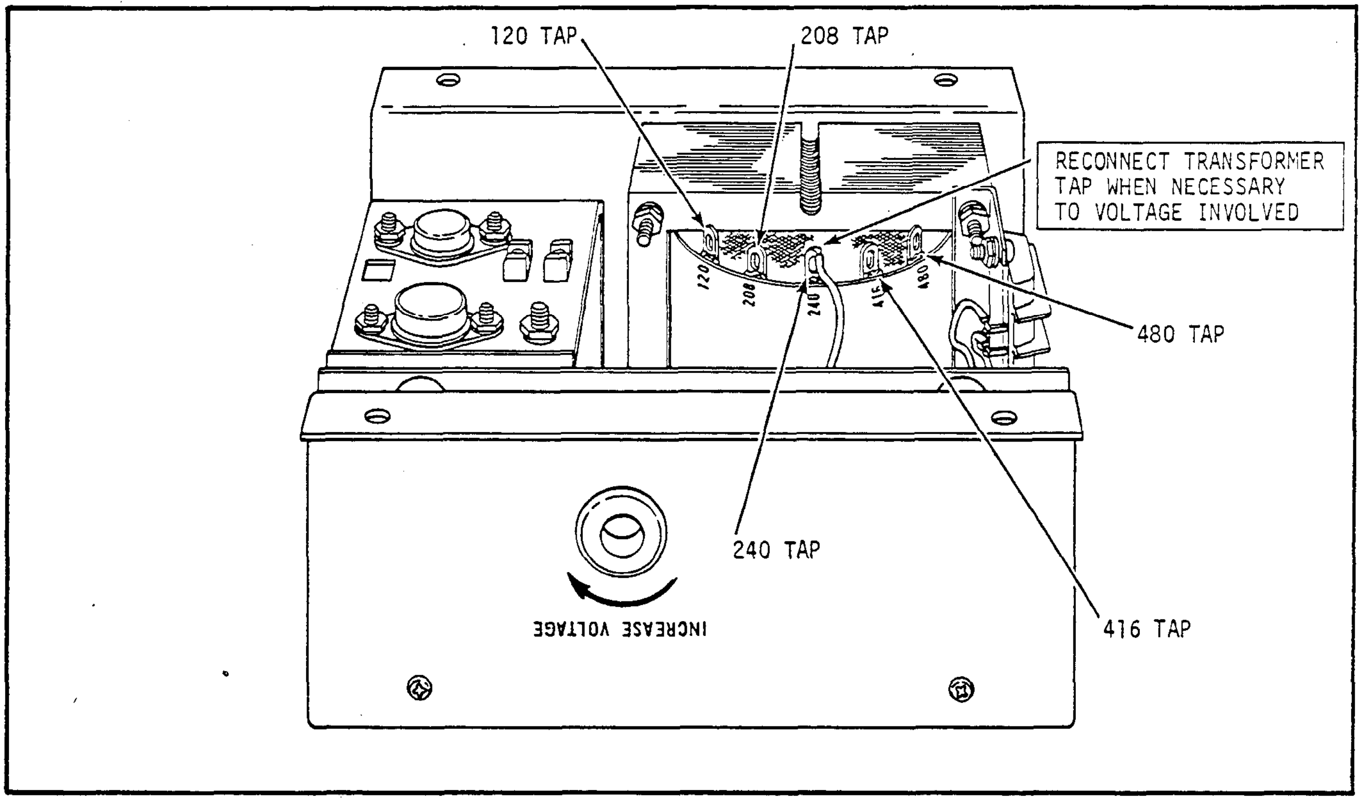


FIGURE 9--Reconnect transformer on Basler regulator for voltage variations

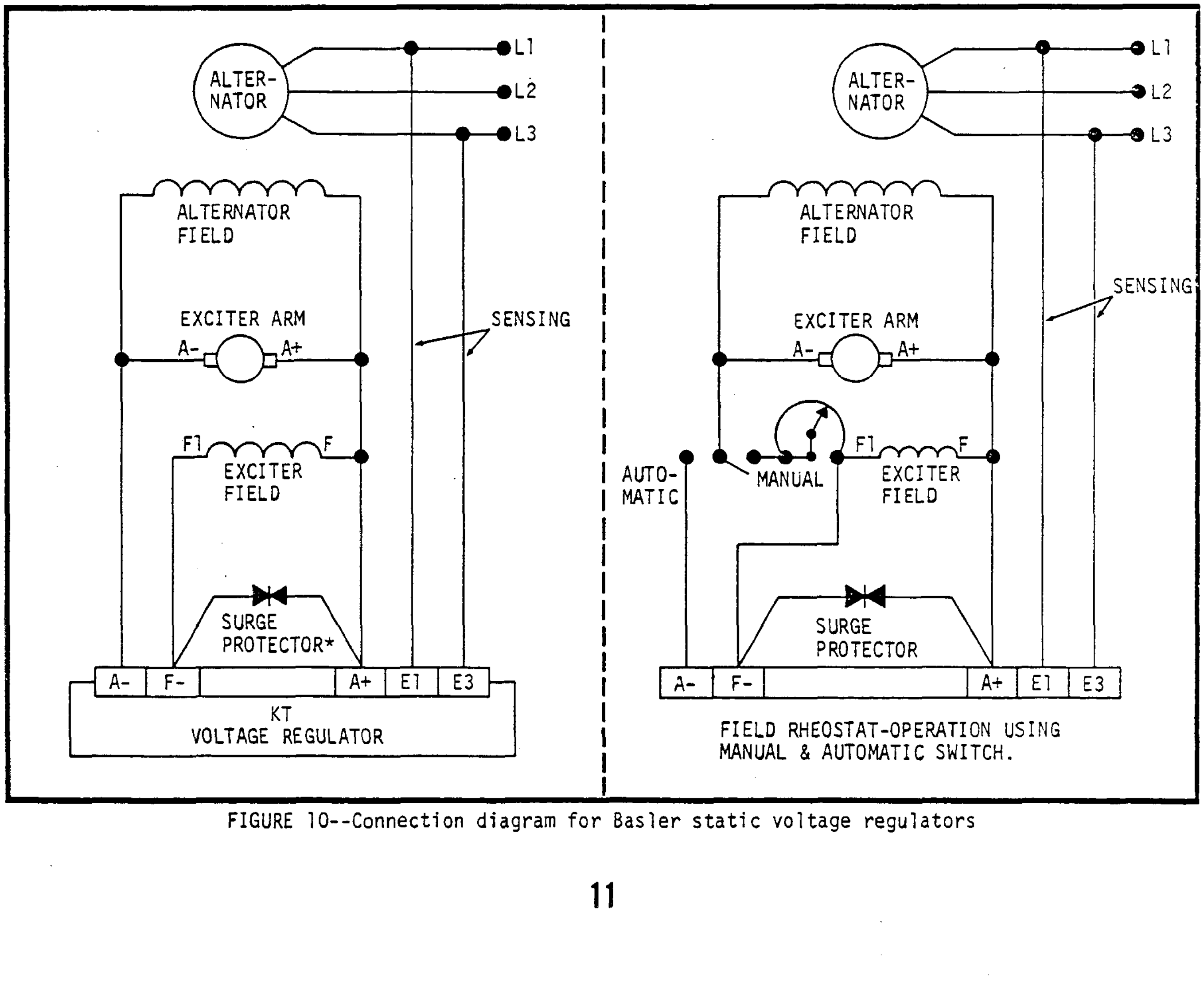


FIGURE 10--Connection diagram for Basler static voltage regulators

TROUBLE SHOOTING-BASLER REGULATOR

TROUBLE SHOOTING: Some of the possible malfunctions that could occur during the installation of the voltage regulator and the appropriate corrective procedures are listed in the accompanying trouble shooting guide.

SYMPTOM	PROBABLE CAUSE	REMEDY
No build-up.	● Residual magnetism too weak or of improper polarity.	Flash the field with correct polarity.
Generator output voltage* rises to maximum voltage.	● Open leads between input terminals E1 and E3 of regulator and alternator terminals. ● Terminal E1 connected to wrong terminal on transformer T1.	● Correct open circuit. ● Make correct connection.
Generator voltage constant but below normal.	● Terminal E1 connected to wrong terminal on transformer T1.	Make correct connection.
Generator output erratic.	● Badly worn, dirty, or improperly seated brushes. ● Dirty commutator.	Replace, clean, or reseat brushes. Clean commutator.

* If Q4 power transistor shorted, replace regulator.

ADJUSTMENT: An internal variable resistor (R6) is provided as a means of adjusting the regulated voltage over a range of ± 10% of the nominal voltage. The adjustment can be made with a screwdriver, inserted through the opening in the side of the unit. A variable resistor can be series connected in either sensing line (terminal E1 or E3) to provide an external voltage adjustment.

CAUTION: During the voltage adjustment, make sure the metal shank of the screwdriver does not touc the sides of the opening or any other metallic object.

PREVENTIVE MAINTENANCE: The voltage regulator should give years of trouble-free service with reasonable care. The following preventive maintenance should be performed.

a. Dust the unit periodically and keep air screens, vents, or ducts free of accumulated dust and other foreign material. Use a soft bristle brush or an air line that has a filter and a moisture trap.
b. Make sure that the air supply is not blocked. The unit will overheat if the air flow is cut off.

GENERAL CHARACTERISTICS - BASLER REGULATORS

INPUT SENSING (TERMINALS E1 & E3)

Voltage	120-208-240-416-480
Frequency	50 - 60 cps.
Phase Sensed	1

INPUT POWER

Rated Armature & Field Windings	125 volts

OUTPUT POWER

Nominal Voltage	125
Forcing Voltage	180
Current	.04 to 2 amps

VOLTAGE ADJUSTMENT

Range (of nominal)	± 10%

VOLTAGE REGULATION: Less than ± 1% for 100% alternator loading and for ± 10% frequency changes.

SHORT CIRCUIT PERFORMANCE: Up to 6 amperes continuous duty capability to the exciter field during short circuits and overloads.

AMBIENT OPERATING TEMPERATURES

Range (Centigrade)	-30° to +60°C

INSTRUCTION MANUA

KOHLER
STATIC EXCITER GENERATORS

STATIC EXCITER

SINGLE PHASE C-284452

THREE PHASE A-284451

STATIC REGULATORS

SINGLE PHASE B-269659

THREE PHASE B-269602

THREE PHASE A-269735

KOHLER CO. of KOHLER, WIS. 53044

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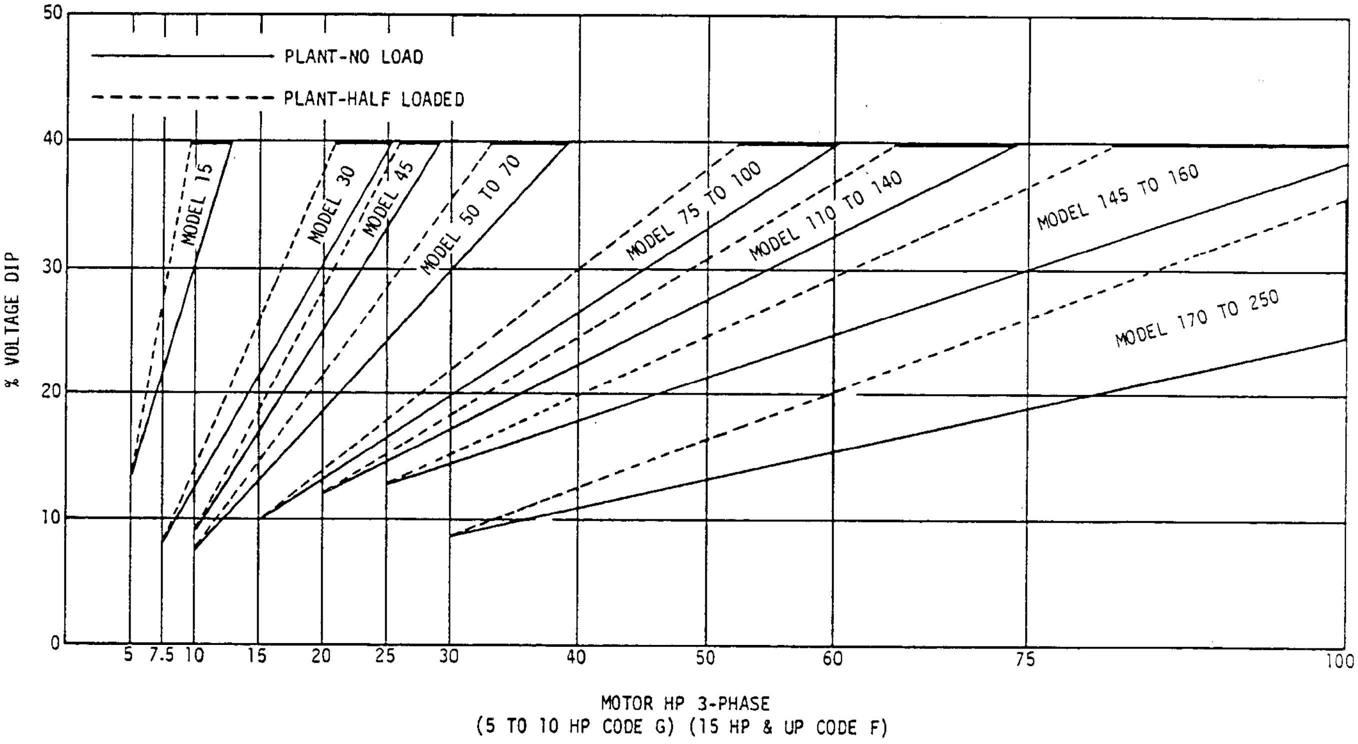
CONTENTS

KOHLER STATIC EXCITER PLANTS

VOLTAGE DIP CURVE



Approximate "voltage dip" anticipated during start up of NEMA Code G and F Induction Motors.

STATIC EXCITER - STATIC REGULATOR GENERATOR

The function of the static exciter and static voltage regulator is to keep the voltage of the alternator at a constant value and deliver fast load response. Excitation is obtained by rectifying a portion of the alternator output voltage and feeding this power back through the alternator field.

The operation of the regulator and exciter is completely static. Their lifetime is not limited by wear of moving parts and they are relatively unaffected by temperature, vibration or shock.

STATIC EXCITER AND REGULATOR CHARACTERISTICS

MANUFACTURER -- Kohler Co.

PART NUMBERS

GENERATORS	REGULATORS	EXCITERS
10 TO 30 KW	3Ø - A-269735	A-284451
45 TO 230 KW	3Ø - B-269602	A-284451
10 TO 230 KW	1Ø - B-269659	C-284452

APPLICATIONS

3Ø Exciters -- Use on 3Ø WYE connected generators only.

Generator Voltages --

120/208 V., 3Ø, 4 wire; 240 V., 3Ø, 3 wire;
240/416 V., 3Ø, 4 wire; 277/480 V., 3Ø, 4 wire;
600 V., 3Ø, 3 wire.

1Ø Exciters -- Use on 3Ø DELTA and all 1Ø generators.

Generator Voltages --

120/240 V., 3Ø DELTA; 120 V., 3Ø DELTA;
120/240 V., 1Ø, 3 wire; 120 V., 1Ø, 2 wire.

Frequency -- 50 - 60 CPS.

NOMINAL EXCITER INPUT

Exciter A-284451 ---------------- 3Ø half wave line to neutral, 120 to 138 V., 16 amps RMS.

Exciter C-284452 ---------------- 1Ø full wave line to "11B" tap, or line to neutral, or 120 volt line to line. 120 to 180 V., 20 amps RMS.

EXCITER OUTPUT

Nominal Field Voltage -- 14 to 80 Average Volts.

Nominal Field Current -- 2 to 28 Average Amps.

Maximum Forcing --

52 Amps with 3 phase exciter A-284451

42 Amps with 1 phase exciter C-284452

REGULATOR SENSING (1Ø on all generators)

208 to 240 Volts (T2-T9) on 3Ø WYE connected generator.
240 Volts (T2-T9) on 3Ø DELTA or 120/240 Volts, 1Ø generator.
120 Volts (L1-L2) on 1Ø, 120 Volts, 2 wire generator.

MINIMUM VOLTAGE ADJUSTMENT ± 10% of nominal.

VOLTAGE REGULATION

2% of Nominal

NEGATIVE FIELD FORCING

The static exciter provides a negative field voltage as high as 60 volts during transient conditions such as sudden load removal. This feature reduces alternator voltage transients in time and magnitude.

AMBIENT OPERATING TEMPERATURE -- -86° F. to +160° F.

WEIGHT

Static Exciter -- 7.5 lb.
Static Regulator -- 1.9 lb.

PRINCIPLES OF OPERATION

Alternator output voltage is sensed by the static regulator. A fraction of this voltage is compared to a reference voltage across a zener diode. Any difference between sensed voltage and reference voltage is transferred to a pedestal circuit. The pedestal circuit utilizes the error to switch a unijunction transistor "on" at a precise angle of wavetime. The unijunction transistor sends signals simultaneously to the gates of all silicon controlled rectifiers in the exciter.

The S.C.R. with the highest anode voltage turns "on" and conducts current through the alternator field. It continues to conduct until another S.C.R. reaches a higher anode voltage. The regulator again sends signals to the gates of all S.C.R.'s and the second S.C.R. conducts current through the field. This sequence occurs three times during one 3Ø generator cycle. The precise angle of wavetime when an S.C.R. turns "on" determines the amount of current it will conduct through the field.

The angle of wavetime is inversely proportional to the sensed output voltage. If the output voltage is low the regulator sends signals sooner to the gates of the S.C.R.'s and they conduct for a longer period of time. The effect is more field current and higher output voltage. Likewise if output voltage is high the regulator sends signals at a later angle of wavetime and the S.C.R.'s conduct for a shorter period of time.

Basic principles of operation are the same for three phase and single phase exciters and regulators. The three phase exciter utilizes three S.C.R.'s in a 30, 4 wire, line to neutral half wave connection. The single phase exciter uses four S.C.R.'s in a 10, full wave bridge connection.

VOLTAGE BUILD UP

The alternator field is initially supplied with battery current as soon as starting switch is moved to "on" position. The battery continues to supply field current until stator generates enough voltage to actuate the static exciter. At this time, a relay in the controller disconnects the battery source of excitation.

SURGE PROTECTION

During short circuits or sudden removal of a load, transient voltages could cause failure of S.C.R.'s if suitable protection is not provided. A surge protector is connected across the alternator field and it effectively reduces the induced voltage to a safe value.

SUPPRESSION

Voltage distortion is controlled at the stator output terminals by three capacitors in the junction box. They are 2 microfarad, 400 volt capacitors. Conductive interference is controlled far below radio bands. Waveform distortion is reduced to a frequency of 5 to 25 kilocycles.

VOLTAGE ADJUSTMENT

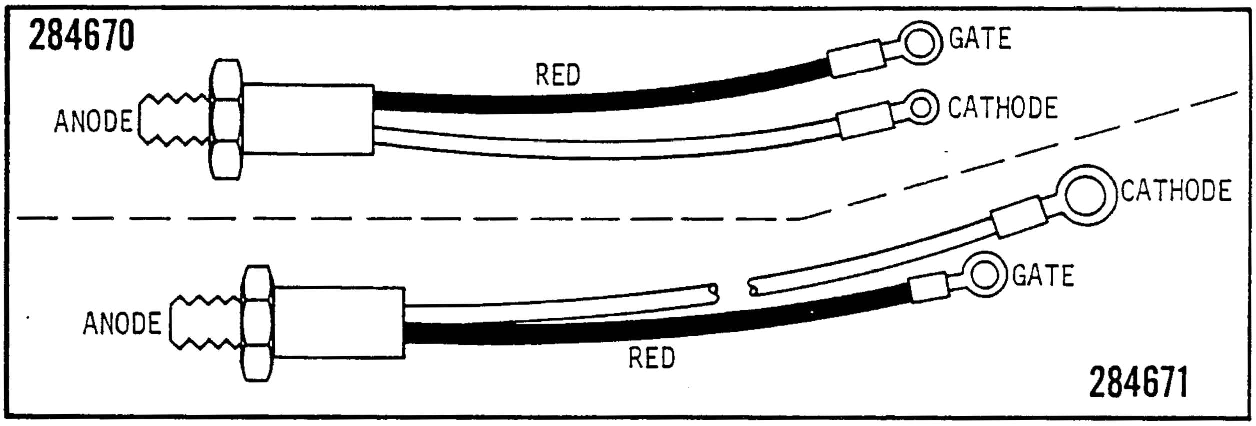
A voltage adjusting rheostat is mounted on the regulator. No other adjustment is necessary. The rheostat has a minimum range of ± 10% nominal voltage. The regulator will provide ± 1% voltage regulation.

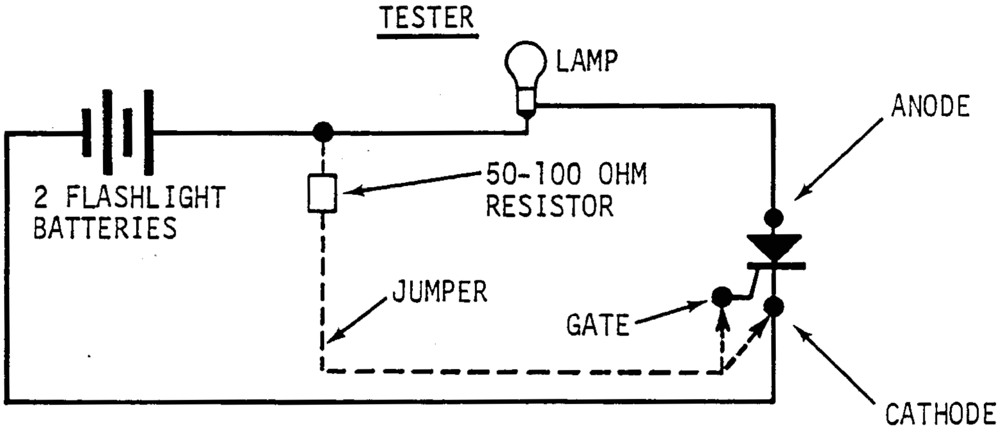
PREVENTATIVE MAINTENANCE

Since the static exciter and regulator are solid state, they are not subject to wear or degradation. However, they should be kept reasonably clean to avoid accumulation of deposits which may reduce cooling.

SILICON CONTROLLER RECTIFIER TEST

The S.C.R.'s in the Kohler Static Exciter can be checked with a simple tester made from two flashlight batteries and a lamp.





S.C.R. TEST

A - Connect negative battery lead to cathode.

B - Connect positive battery lead in series with lamp to anode.

C - Lamp should not glow.

D - Momentarily touch jumper to gate.

E - Lamp should continue to glow after removing signal.

F - Momentarily touch jumper to cathode.

G - Lamp should stop glowing.

STATIC EXCITER REVOLVING FIELD GENERATORS

TROUBLE ANALYSIS

CONDITION	POSSIBLE CAUSE	ELIMINATION CHECKS
No Voltage	Build-up Circuitry	A - Controller fuse or field circuit breaker open. B - Exciter fuses open on single phase exciter. C - Connections loose or broken. D - Brush contact poor. E - Build-up relay contacts not closing in de-energized position. F - Exciter resistor R1 failed open. G - Shorted SCR's on three phase exciter (exciter fuses must be okay). Shorted SCR's 1 or 2 on single phase exciter. H - Rotor circuit open or grounded. I - Controller diode RE1 grounded or open. J - Shorted surge protector.
No Voltage	Short Circuit AC Output	A - Stator connected wrong (refer to Electric Plant Bulletin #397 or 421 for proper wiring). B - External wiring shorted. C - Circulating current high. D - Load ground not the same as generator ground.
Low Voltage	Regulator Malfunction	A - Loose connections. B - Incorrect wiring. C - Regulator defective. D - TEST: Hold build-up relay in de-energized position momentarily. If AC output voltage doesn't rise, the regulator is not at fault. If voltage rises to a high level, regulator is malfunctioning. (This test assumes that R11, R12 and R13 resistors in the regulator are operable.)
Low Voltage	Controller Faulty	TEST: Check voltage between terminal 20 and ground when starting switch is closed--12 or 24 volts should be present (dependent on starting battery voltage). If no voltage is observed, Controller is faulty. Check for improper wiring or faulty relays.
Low Voltage	Exciter Faulty	TEST: Approximately 4 volts or more DC should be present across collector rings during build-up. If less than this, exciter may be at fault. Check the following: 1. Fuse open. 2. SCR's shorted or open. 3. SCR's not switching - About 16 to 20 volts DC must be present across collector rings with plant running (no load) or else exciter may have SCR's which do not switch due to high gate requirements.
Low Voltage or No Voltage	Generator	A - Rotor may be grounded or partially shorted. Check rotor for proper resistance and no ground. Refer to Electric Plant Service Bulletins #397, 420 and 421. B - Stator ungrounded. C - Stator leads connected wrong.
High Voltage	Controller Faulty	A - TEST: Start plant and allow it to come up to speed, then immediately disconnect excitation lead at terminal 20. If voltage does not return to normal, trouble is in regulator or exciter. If it returns to normal, controller circuitry is at fault. B - AC relay not opening the build-up circuitry. (Some push button controllers use a DC relay for the build-up circuit with a rectifier. Relay fails due to rectifier failure.) C - Trace build-up circuitry thru controller as per controller diagram.
High Voltage	Regulator Faulty	A - Open regulator circuit breaker. If voltage recedes regulator is faulty, sensing circuit is open or regulator terminal 1 is not connected to proper exciter terminal 35 or R1. B - If plant has no circuit breaker remove jumper on regulator terminals A and B and replace with toggle switch to simulate circuit breaker. C - 208/240 volts should be obtained across regulator terminal 8 and 10 or sensing circuit wires are not properly connected to stator leads. D - Check for loose connections. E - Check rheostat setting.
Voltage Fluctuation	(See next column)	A - Defective regulator. B - Poor brush contact. C - Defective build-up relay. D - Loose capacitor connections. E - Loose electrical connections. F - Defective SCR.

GENERATOR CONNECTIONS

The following diagrams show the standard (voltage) connections for Kohler plants in the 15 to 250 KW range with LO terminal grounded--if any other terminal is grounded, contact Electric Plant Engineering before reconnecting. With the exception of the 3 phase 600 volt plant, these plants can be reconnected to obtain different standard voltages. The static exciter and regulator may in some cases have to be changed--if, for example, reconnecting from a 3 phase 4 wire Wye to 3 phase 4 wire Delta, both would have to be changed to those listed for the Delta connection in the chart below.

PLANT CHARACTERISTICS				REF. FIGURE		STATIC EXCITER		STATIC REGULATOR		
PHASE	WIRES	VOLTAGE	TYPE	15-85 KW	100-200 KW	A-284451	C-284452	B-269602*	B-269659	B-269735*
1	2	120 V	4 lead	1	5	-	X	-	X	-
1	3	120/240	12 lead	3	4	-	X	-	X	-
1	3	120/240	4 lead	2	6	-	X	-	X	-
3	4	120/240	Delta	8	7	-	X	-	X	-
3	4	120/240	Delta	-	9	-	X	-	X	-
3	4	120/208	Wye	10	10	X	-	X	-	X
3	3	240 V	Wye	10	10	X	-	X	-	X
3	4	277/480	Wye	11	11	X	-	X	-	X
3	3	600 V	Wye	12	12	X	-	X	-	X

* B-269602 used on plants above 30 KW, B-269735 used on plants 30 KW and smaller.

On some 3 phase plants, the voltage can be changed to another standard voltage simply by changing the setting of the regulator rheostat--for example, 208 to 240, 416 to 480, etc. If changing 3 phase from 208 to 240 V or 416 to 277/480 V, connect generator lead #11A (instead of 11) to Controller terminal 11.

Note that a change in voltage may also affect the battery charging rate on plants where battery charging is provided by the exciter--automotive type charging not affected. The battery charging leads are 15, 16, (or 16A) and 17. Lead 15 is common and is always connected to terminal 15 in the Controller. If an increased charging rate is necessary, disconnect Controller lead 16 from generator lead 16 and reconnect it to generator lead 16A or 17. Reverse this procedure to reduce the charge rate. Also note that when reconnecting from 3 phase to single phase, the capacity will be reduced. Capacitor unit A-283923 used with 3 phase generators; A-284345 with single phase generators.

SINGLE PHASE CONNECTED GENERATOR

Certain generators are designed for 1Ø only. They have 4 leads. The exciter and regulator are connected to the same terminals as the 12 lead generator. The 4 lead generator can be reconnected for 120 V., 2 wire applications by paralleling the coils. Connect T3 to T1 and T4 to T2. When this is done, both exciter and regulator are connected to L1 and L2 and 11-B is not used.

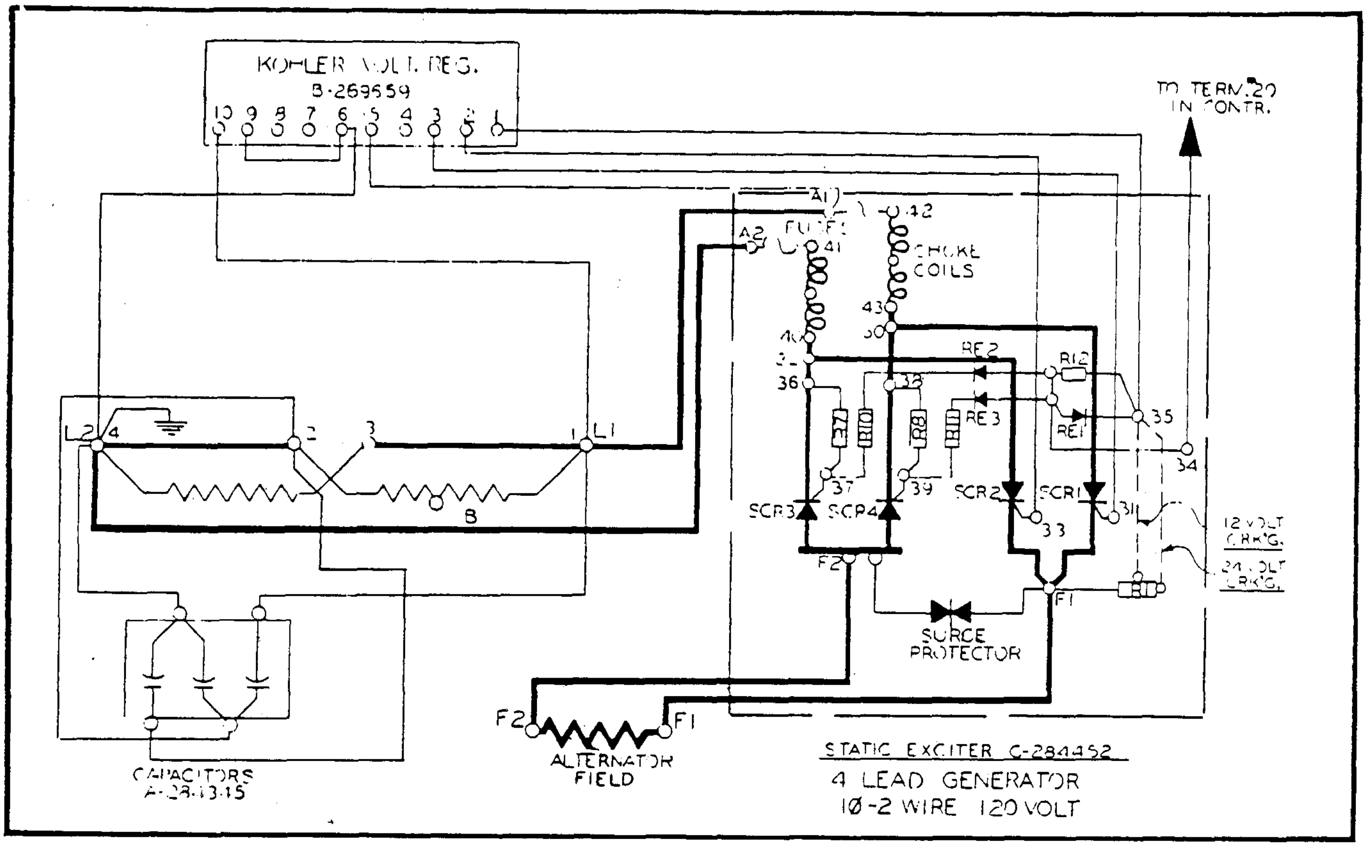


FIGURE 1 -- 1 Ø - 2 WIRE 120 VOLT 4 LEAD GENERATOR

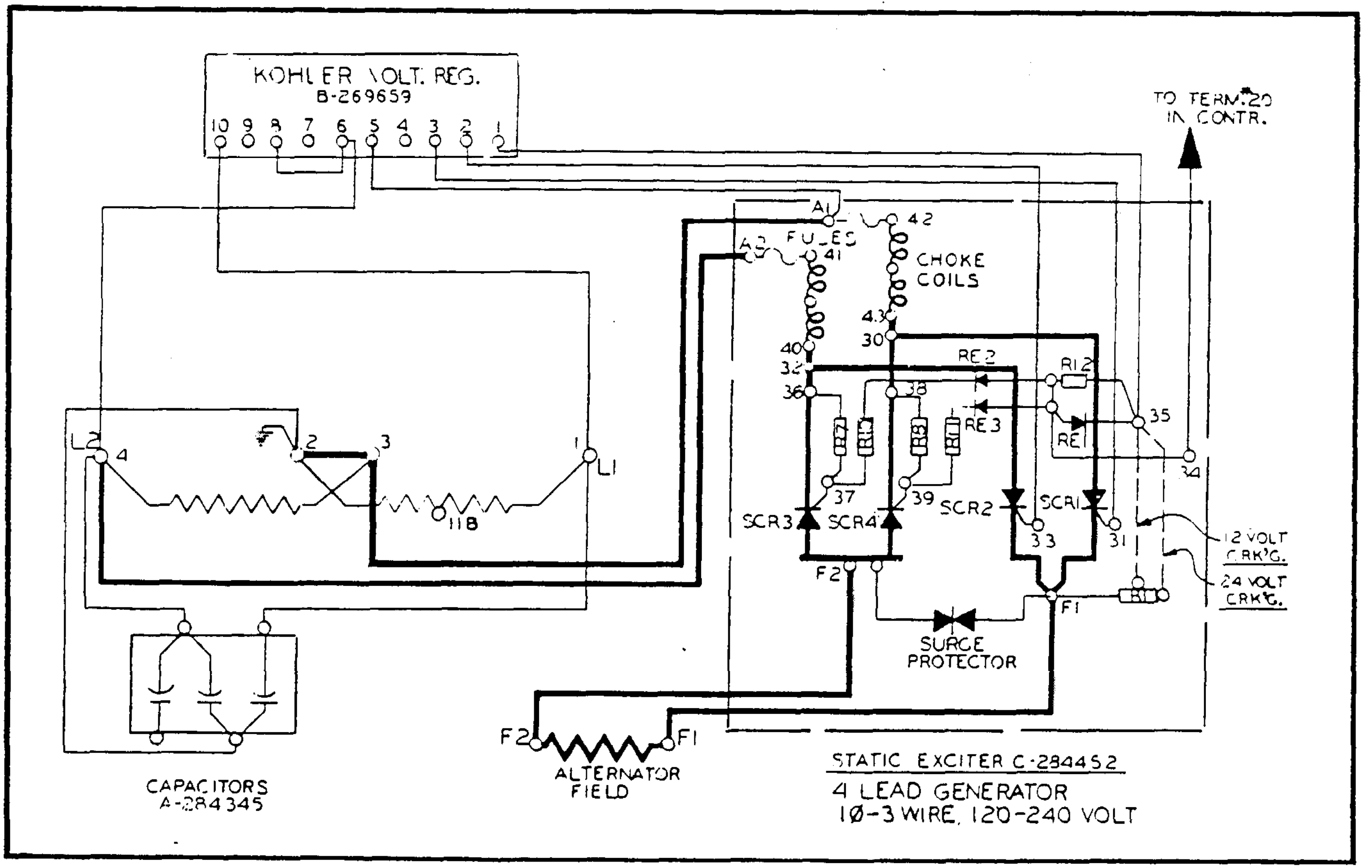


FIGURE 2 -- 1 Ø - 3 WIRE 120-240 VOLT 4 LEAD GENERATOR - 15-85 KW

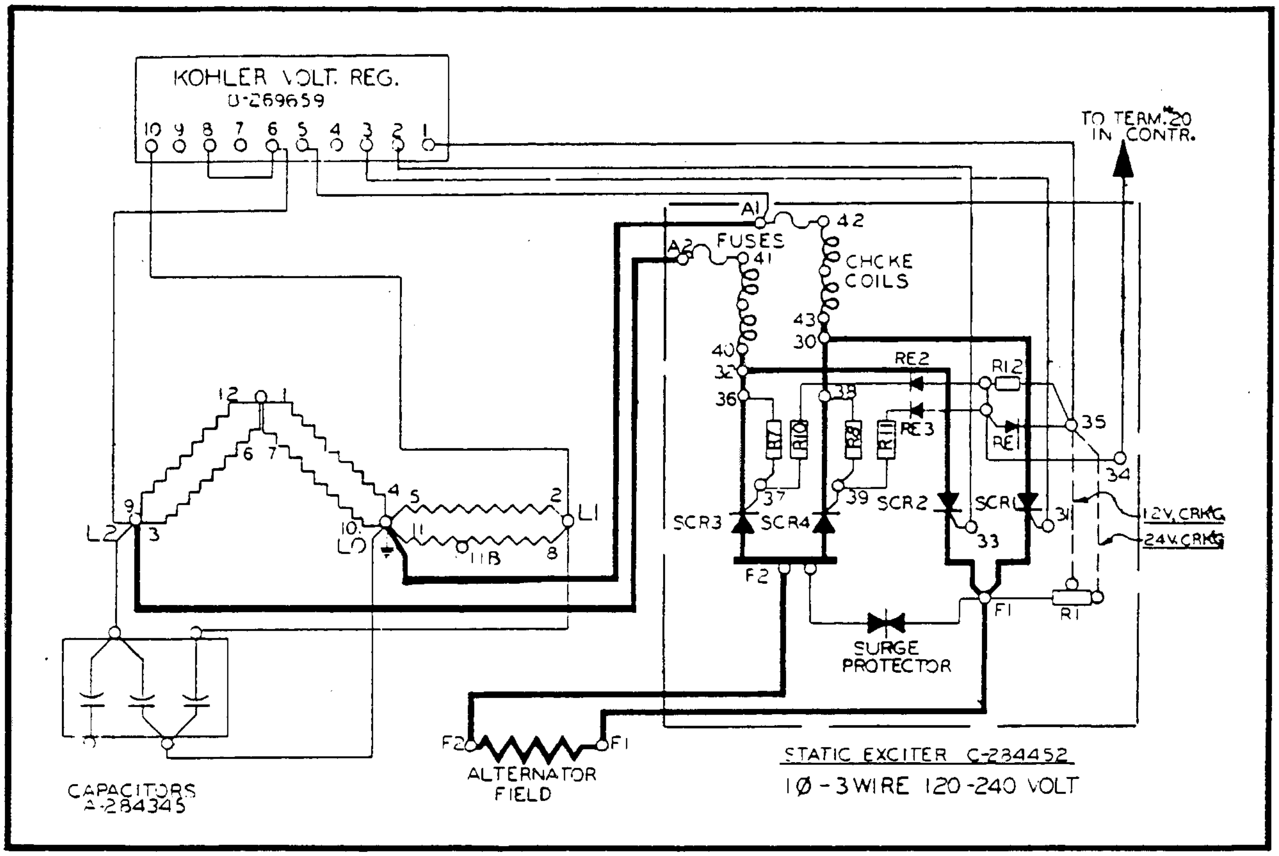


FIGURE 3 -- 1 Ø - 3 WIRE 120-240 VOLT 12 LEAD GENERATOR - 15-85 KW

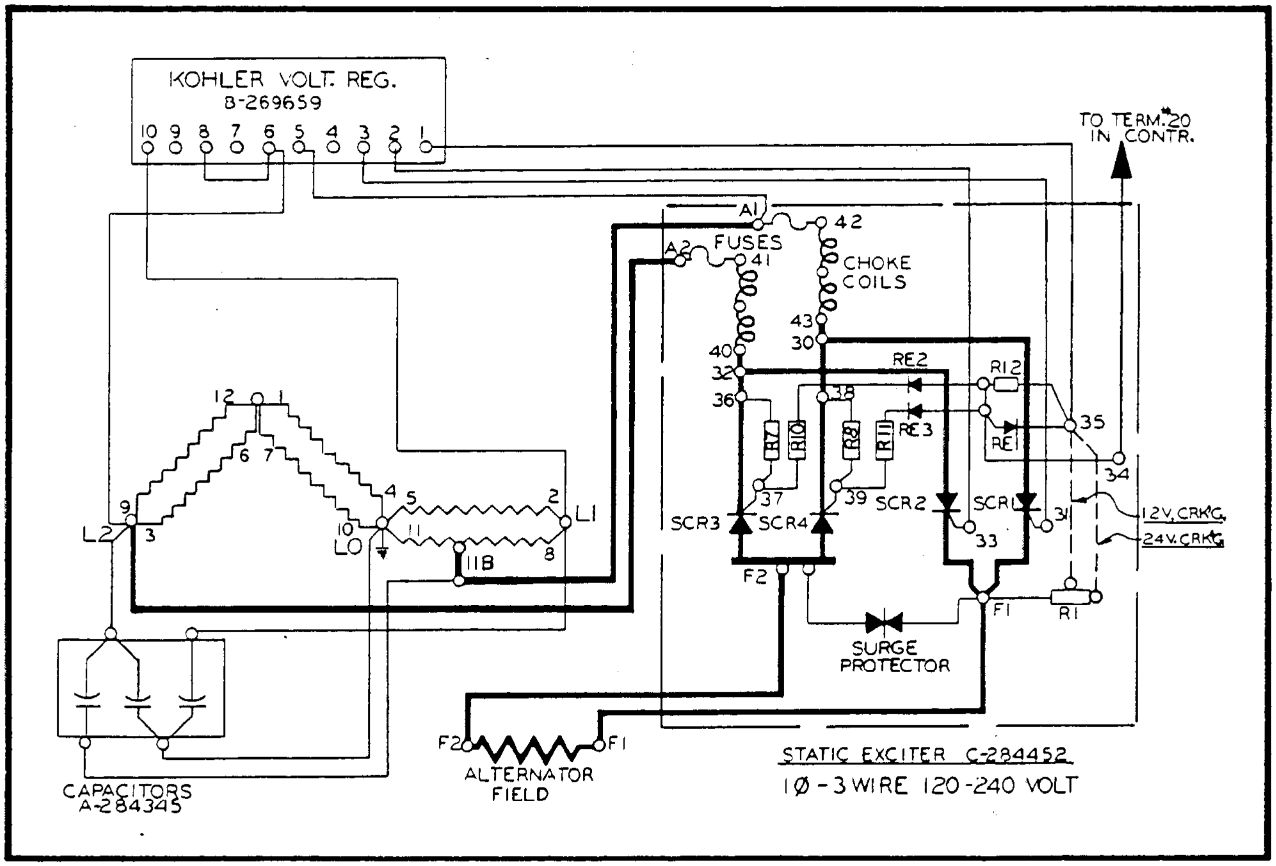


FIGURE 4 -- 1 Ø - 3 WIRE 120-240 VOLT 12 LEAD GENERATOR - 100-250 KW

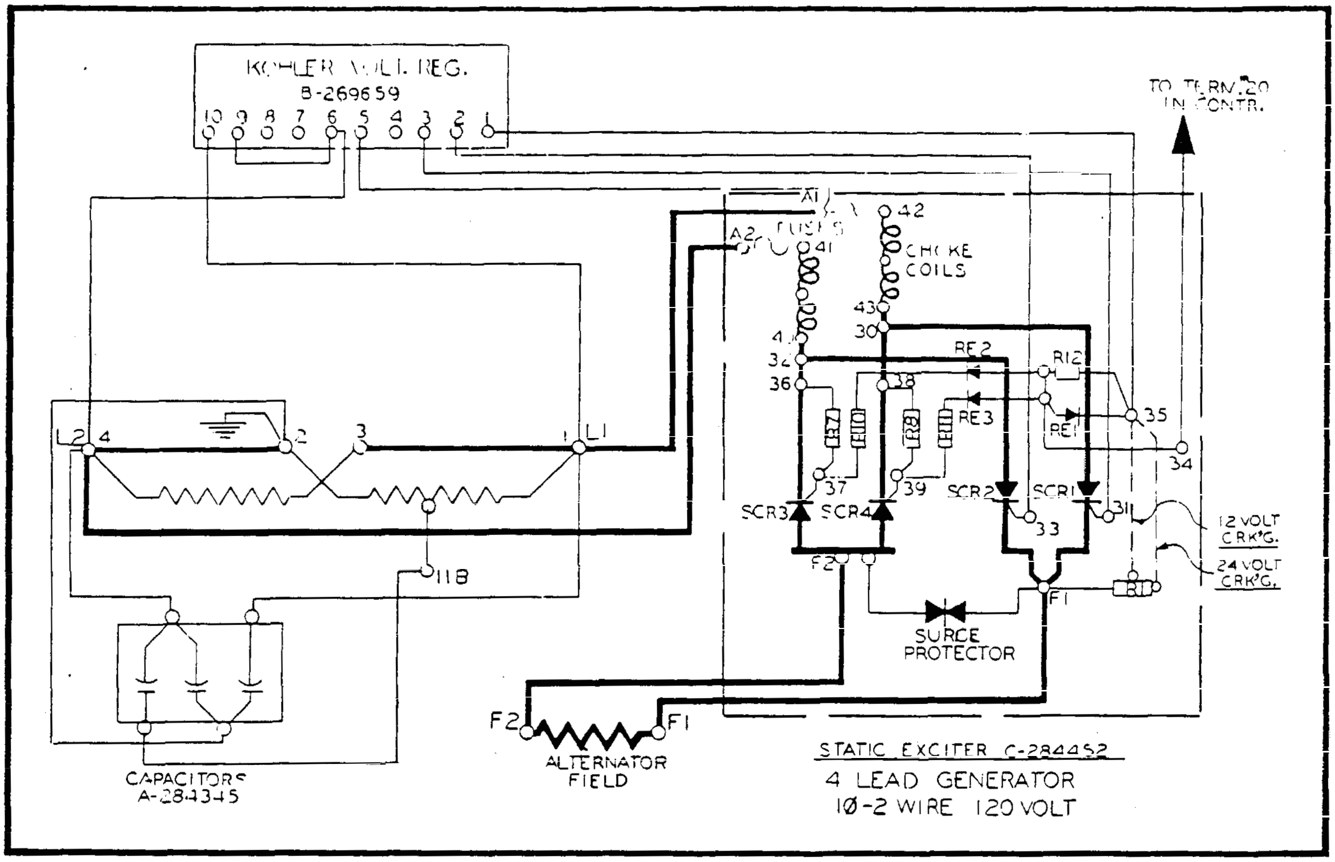


FIGURE 5 -- 1 Ø - 2 WIRE 120 VOLT 4 LEAD GENERATOR - 100-250 KW

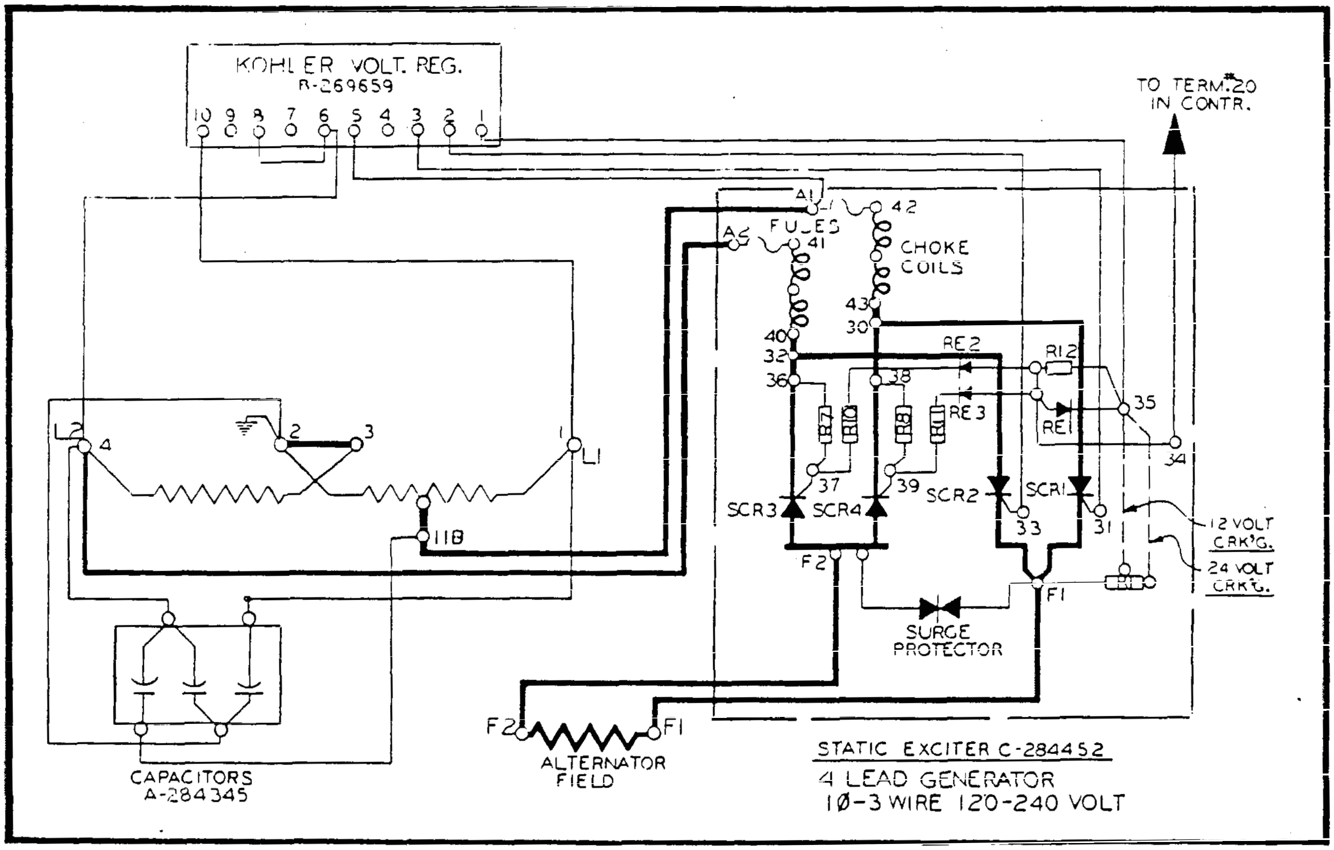


FIGURE 6 -- 1 Ø - 3 WIRE 120-240 VOLT 4 LEAD GENERATOR - 100-250 KW

3 PHASE DELTA CONNECTED GENERATOR

The 120-240 V., 3 Ø, Delta connected generator is essentially connected as shown in Figure 7. Note that the exciter is connected to L2 and 11-B generator leads and the regulator is connected to L3 and L2.

The generator can be changed to 120 volts, 3 Ø, 3 wire by paralleling generator coils. When this is done, both the exciter and regulator are connected to L2 and L3, and 11-B is not used.

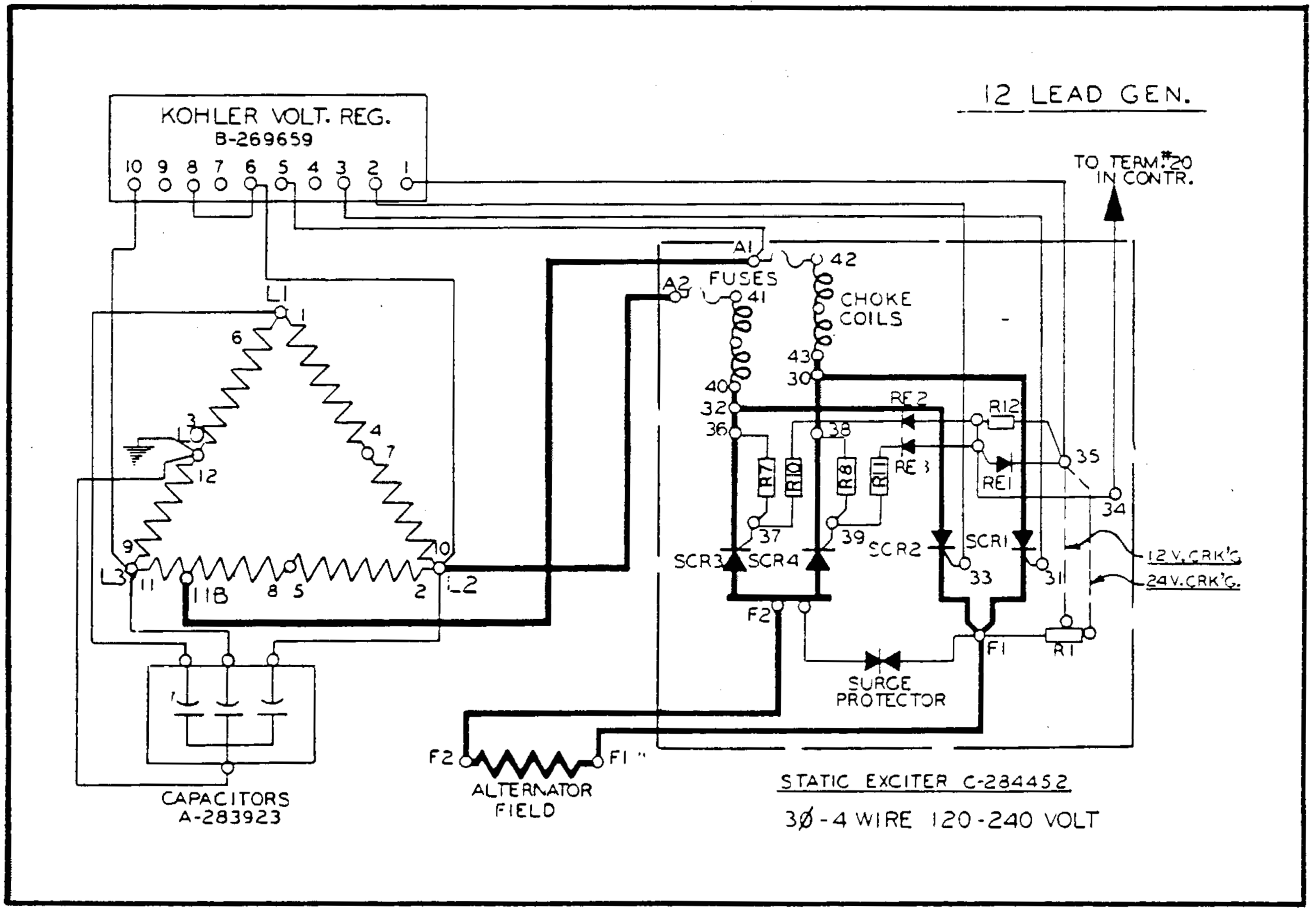


FIGURE 7 -- 3 Ø - 4 WIRE 120-240 VOLT 12 LEAD GENERATOR - 100-250 KW

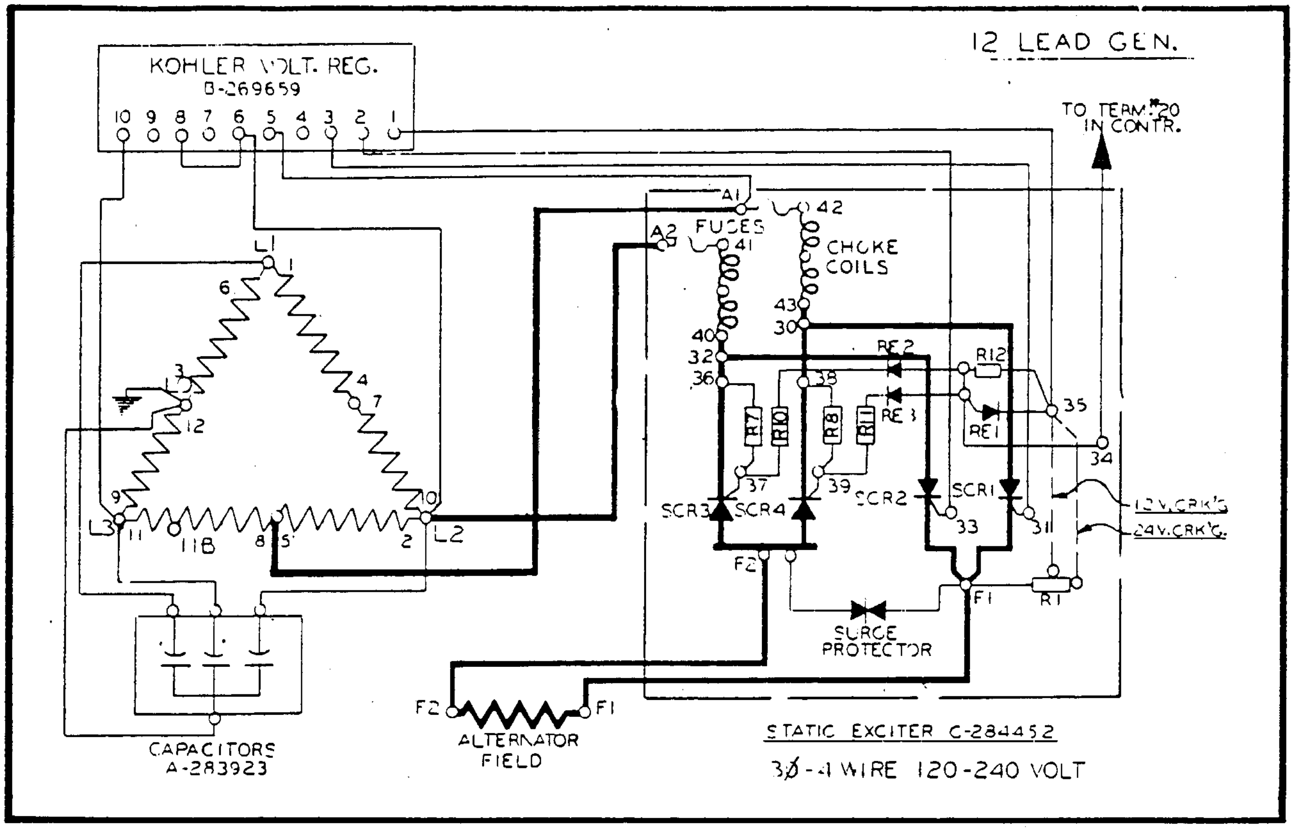


FIGURE 8 -- 3 Ø - 4 WIRE 120-240 VOLT 12 LEAD GENERATOR - 15-85 KW

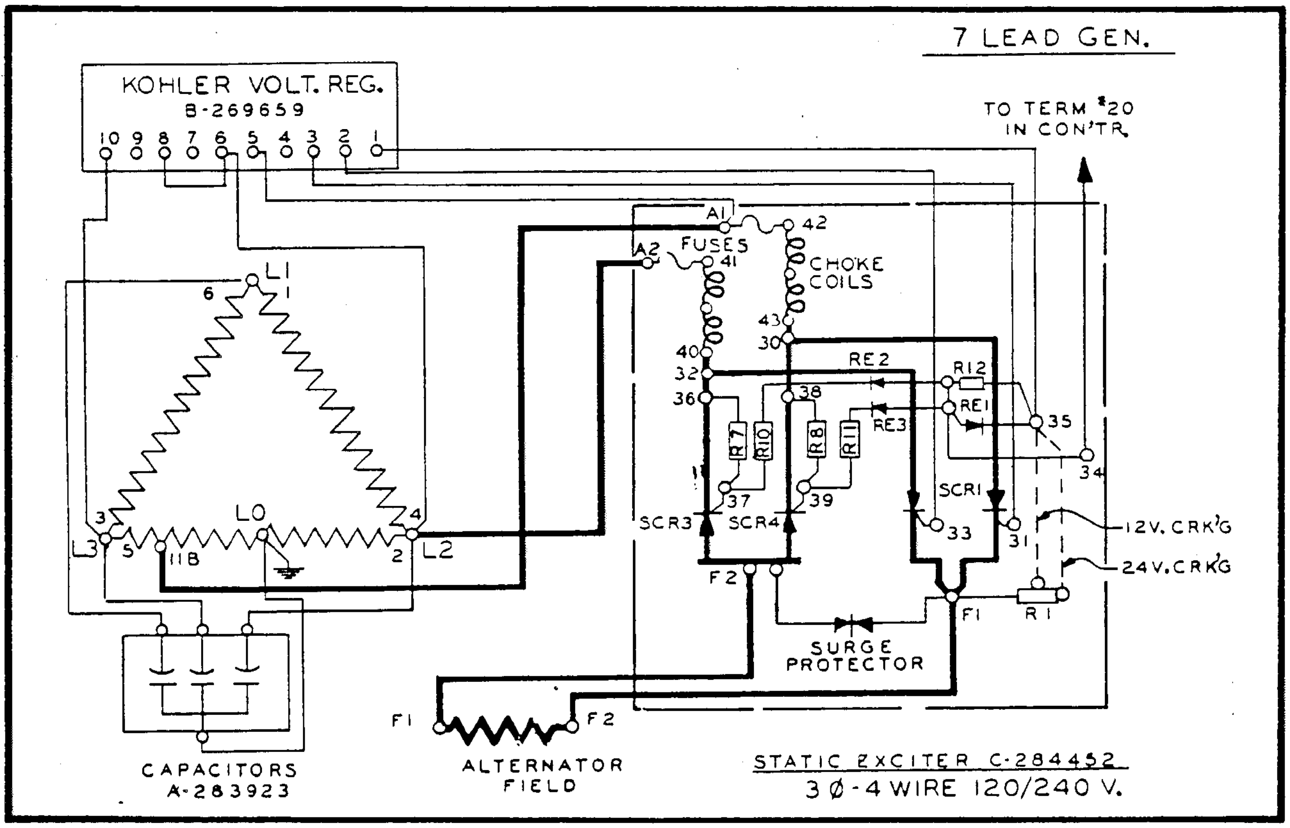


FIGURE 9 -- 3 Ø - 4 WIRE 120-240 VOLT 7 LEAD GENERATOR - 100-250 KW

3 PHASE WYE CONNECTED GENERATORS

All WYE connected generators are essentially connected as shown in Figure 10. Note that the exciter and regulator are connected to T7, T2 and T9 generator terminals. In this low voltage connection, the terminals are common to L1, L2 and L3, but they will not be common on a high voltage (480 V.) connection. It is only important that the exciter and regulator be connected to a 3 Ø source of 120 to 137 volts line to neutral and the source will be terminals T7, T2 and T9 on all standard generators. The 600 volt generator has terminals marked 1B, 2B and 3B for a 3 Ø source of 120 volts.

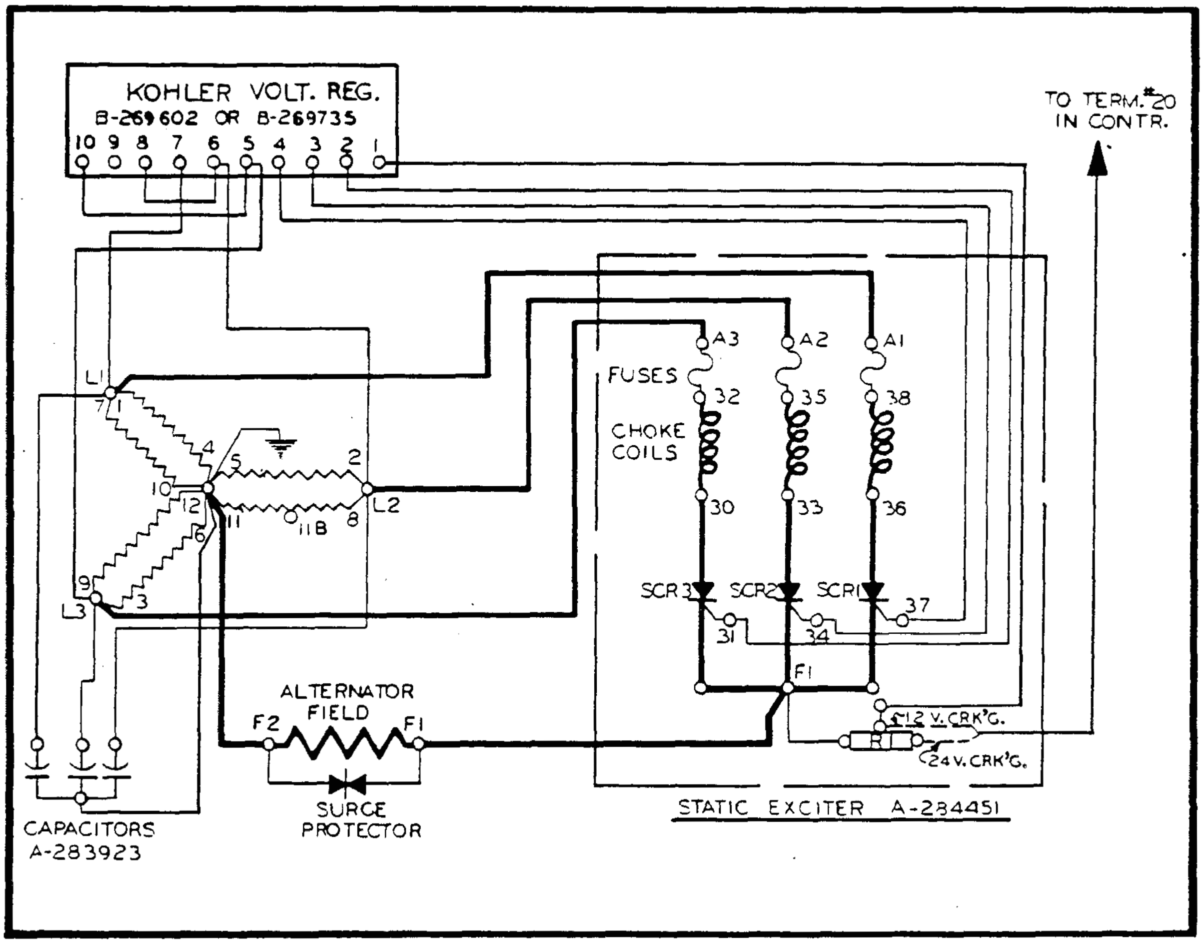


FIGURE 10 -- 3 Ø - 4 WIRE 120-208 VOLT, 3 Ø - 3 WIRE 240 VOLT - 15-250 KW

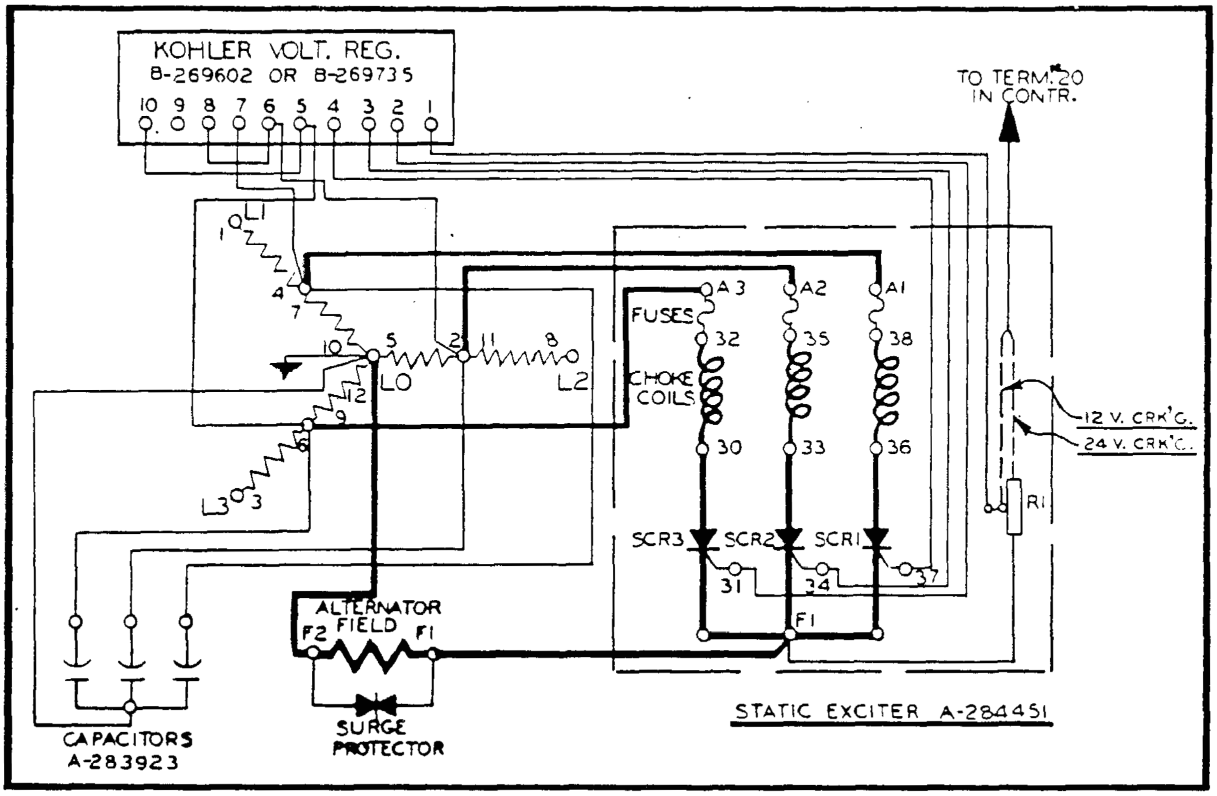


FIGURE 11 -- 3 0 - 4 WIRE 277-480 VOLT - 15-250 KW

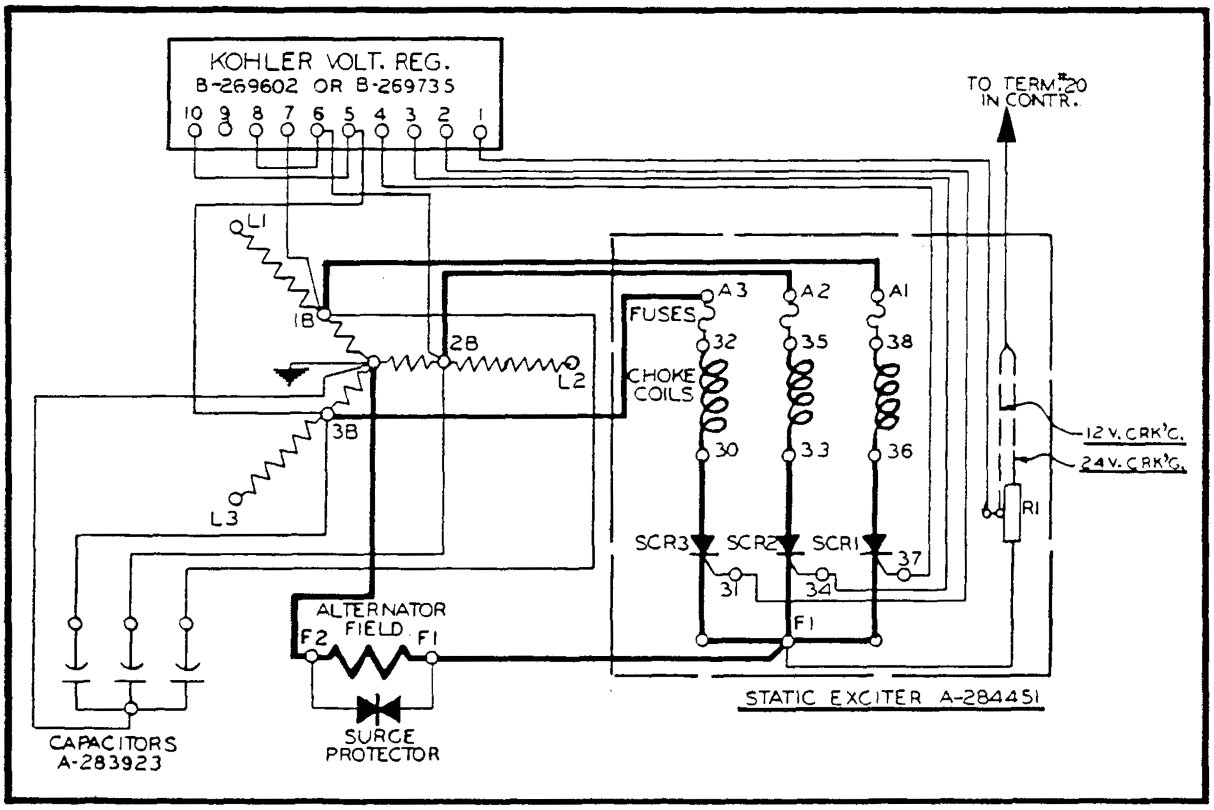
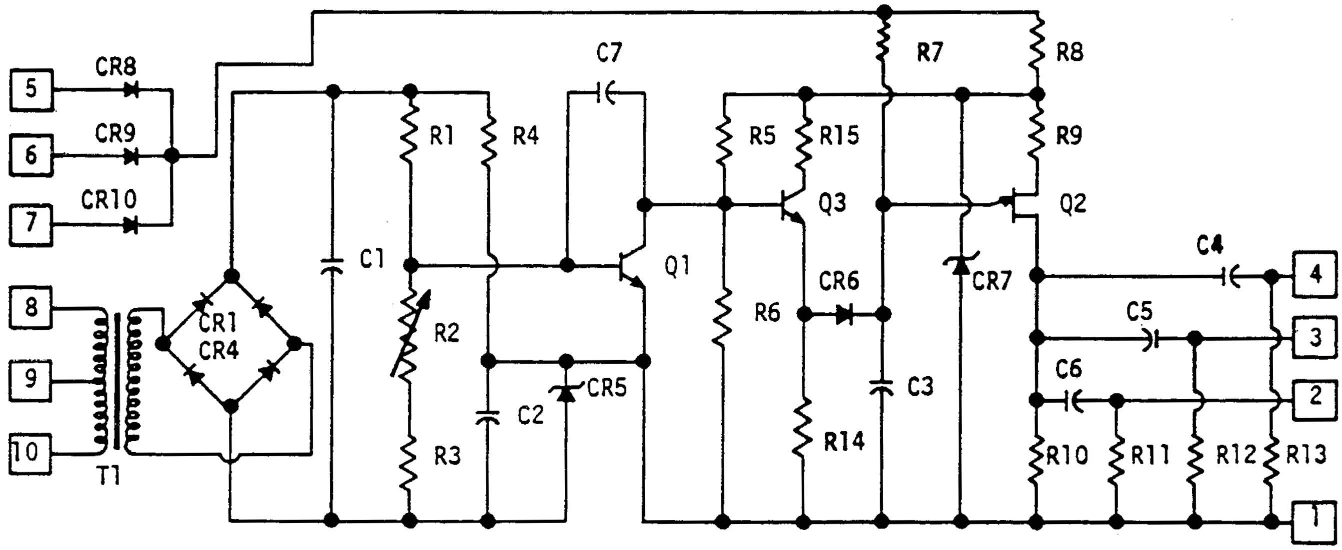


FIGURE 12 -- 3 0 - 3 WIRE 600 VOLT 4 LEAD GENERATOR - 15-250 KW

3 PHASE STATIC REGULATOR B-269602

Generator output voltage is transformed and rectified by transformer T1 and rectifier CR1-CR4. A sensing circuit primarily consisting of rheostat R2, transistor Q1 and reference diode CR5, detects any change in generator output requirements. The difference between sensed generator voltage and the reference voltage across zener diode CR5 is utilized to control a pedestal circuit.



The pedestal circuit determines the exact angle of wavetime that capacitor C3 becomes fully charged. When C3 is fully charged, a voltage potential is present across the emitter and base of unijunction transistor Q2. At exactly 12 volts Q2 is biased "on" and a pulse signal is sent to the gates of the silicon controlled rectifiers in the exciter. The S.C.R. with the highest anode voltage turns "on" and instantaneously conducts current through the field. It continues to conduct until another S.C.R. has a higher anode voltage.

1Ø static regulators are basically the same as 3Ø regulators. However, the regulators cannot be interchanged due to technical differences.

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