





# TECHNICAL REFERENCE MANUAL

## S100

For Northern Lights Generator Sets

NORTHERN LIGHTS®

www.northern-lights.com

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# Selection & Installation Guide

for Prime and Stand-By Power Generator Sets

## CHOOSING THE RIGHT GENERATOR SET

Once you've decided to purchase a generator set, there are several considerations you must keep in mind when choosing which set to buy, where to install it and how to install it. This guide will help you make informed decisions during the selection and installation process.

Choosing the right set is not difficult if you take the time to analyze your requirements carefully. You will also need to know a few terms and have a basic understanding of the different types of generator sets and their operating principles.

Installation requires expert assistance and a strict adherence to local codes and regulations. We recommend that you have a contractor do your installation or, at the very least, have him provide professional advice.

## STAND-BY OR PRIME?

The first determination you will need to make is whether you will require stand-by or prime power. Simply stated, prime power is required when you have no other source of power. A stand-by set steps in and picks up designated loads when your main power supply is not available.

## GAS OR DIESEL?

There are three main components to a generator set: A diesel or gas "engine" which drives an electrical "generator end" and is monitored/governed by various "controls."

Engines are either spark ignited (gas, natural gas, propane) or compression ignited (diesel). Diesel engines are better for heavy duty and last longer. Diesel fuel is also less combustible, making it safer to handle and store.

## OPERATING SPEED

Electric equipment is designed to use power with a fixed frequency: 60 Hertz (Hz) in the United States and Canada, 50 Hertz in Europe and Australia. The frequency output of a generator depends on a fixed engine speed. To produce 60 Hz electricity, most engines operate at 1800 or 3600 RPM. Each has its advantages and drawbacks.

1800 RPM, four pole sets are the most common. They offer the best balance of noise, efficiency, cost and engine life. 3600 RPM, two pole sets are smaller and lightweight, best suited for portable, light-duty applications.

## FEATURES & BENEFITS TO LOOK FOR

- **Engine block.** For long life and quiet operation we recommend four cycle, liquid cooled, industrial duty diesel engines.
- **Air or liquid cooling.** Air cooled engines require a tremendous amount of air and may require ducting. They're noisy too. Liquid cooling offers quieter operation and more even temperature control.
- The **fuel system** should be self venting. Engine speed should be governed by a mechanical or electronic governor. It is best to have an on-engine fuel filter with a replaceable element.
- **Intake and exhaust.** Time and money savers include a large, integral air cleaner with replaceable filter element and a residential muffler which is built into the exhaust manifold. This saves the need for an additional muffler.
- The **lubrication system** should have a full flow, spin-on oil filter with bypass.
- **DC electrical system.** Standard 12 volt system should include: • starter motor and battery charging alternator with a solid state voltage regulator • quick disconnection plug-in control panel with hour meter • pre-heat switch and start/stop switch • safety shutdown system to protect the engine in case of oil pressure loss or high water temperature • DC system circuit breaker.
- **AC generator** should have a 4 pole revolving field. An automatic voltage regulator will provide "clean" power.
- A **steel skid frame** keeps everything in one piece and eases installation. Vibration mounts isolate engine vibration for smooth, quiet operation.
- Finally, every set should be test run under load and include a complete set of operator's and parts manuals.

## WHAT SIZE SET WILL I NEED?

Sizing is the most important step, nothing is more critical in your choice of a generator. A set that is too small won't last, will smoke and can do damage to your electrical equipment. If it is too large, the engine will carbon up, slobber fuel and run inefficiently. We recommend that a generator set never run continuously with less than 25% load. 35% to 70% is optimum.

Additional factors which may affect efficient operation of your generator are high altitude and high air temperature. These conditions will lower generator output. Consult your supplier for de-ration information.

## ESTIMATING YOUR LOAD

To estimate your electrical load, total the wattage of all the equipment you'll operate at one time. The wattage needed to run a given piece of equipment is usually listed on its nameplate. If only amperage is listed, use this formula to figure wattage:

**Amps x Volts = Watts (Single Phase)**

**Amps x Volts x 1.73 = Watts (Three Phase)**

In addition to load requirements, it is important to consider motor starting load. Starting a motor requires up to five times more wattage than running it. Selecting a generator which is inadequate for your motor starting needs may make it difficult to start motors in air conditioners or freezers, for example. In addition, starting load causes voltage dips, which is why the lights dim when a large motor is started. These voltage dips can be more than annoying. They can ruin delicate electronic equipment such as computers.

A reliable method for factoring both running and starting wattage is to take the running wattage of your largest motor and multiply by ten. Then add the running wattages of all the smaller motors as well as the wattage of all the other loads. This will add up to your total load. Next, determine how much of the load will be operating at any one time. This is your running load. Note: If a motor can be wired up at different voltages, for example 120 volt or 240 volt, it is usually more efficient to wire it at the higher voltage.

## ENGINE ACCESSORIES AND CONTROLS

After you determine the generator size you will need, make a list of optional and installation equipment you require. For noise abatement, we recommend a muffler, if one is not built-in, and an exhaust elbow. A good primary fuel filter/water separator is a must to protect your engine's fuel system. You will also need a control panel with gauges to monitor your set **(1)** – see drawing at right. Stand-by sets may require a block heater to keep the coolant/water mix at an adequate temperature for easier starting.

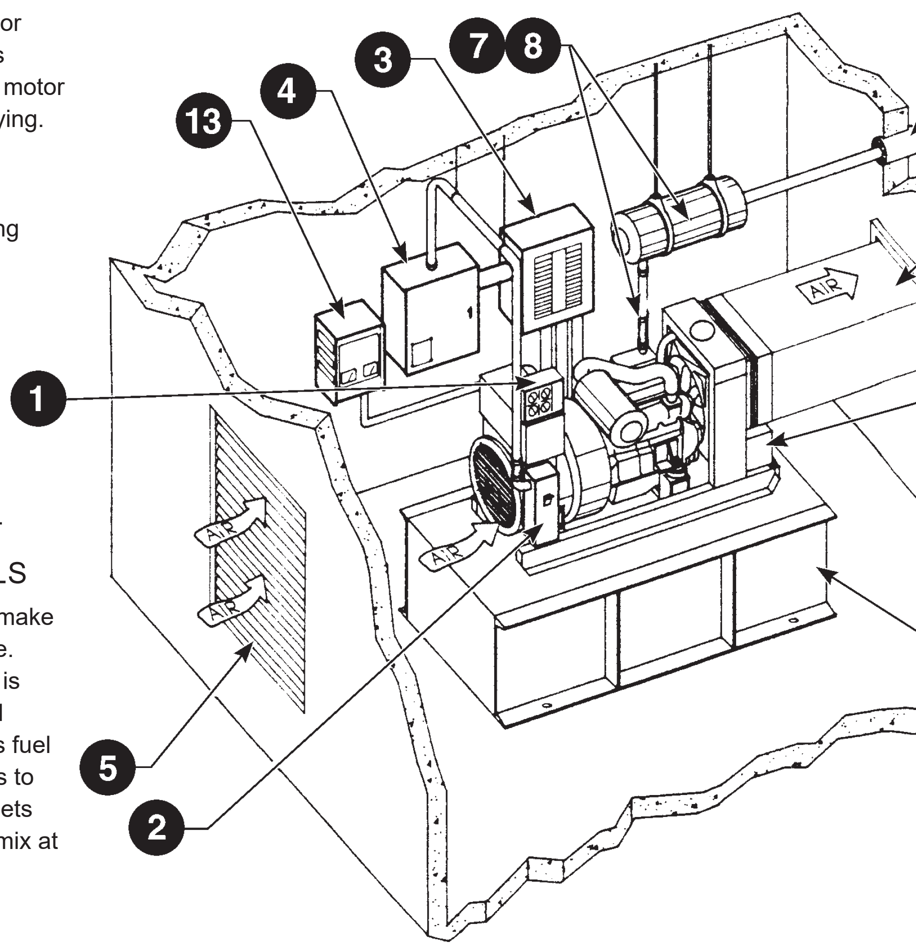
## GENERATOR TYPES & FEATURES

Generator sets produce either **single or three phase power**. Choose a single phase set if you do not have any motors above five horsepower. Three phase power is better for motor starting and running. Most homeowners will require single phase whereas industrial or commercial applications usually require three phase power.

Three phase generators are set up to produce 120/208 or 277/480 volts. Single phase sets are 120 or 120/240. Use the low voltage to run domestic appliances and the high voltage for your motors, heaters, stoves and dryers.

**Regulation** is how closely the generator controls its voltage output. Closer regulation is better for extended motor life. An externally regulated generator has an automatic voltage regulator and holds a ±1% to 2% voltage tolerance.

**Temperature rise** is a measurement of the increase in heat of the generator windings from no load to full load. What it tells you is the quantity of copper in the generator. The lower the temp-rise, the more copper and the better the quality. A 105°, or lower, temp-rise is recommended for both commercial and residential prime power sets.



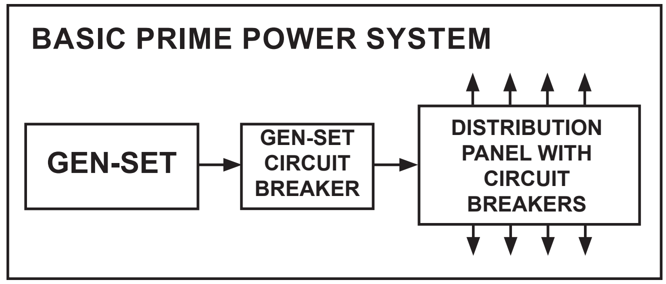
## AC SWITCHGEAR AND CONTROLS

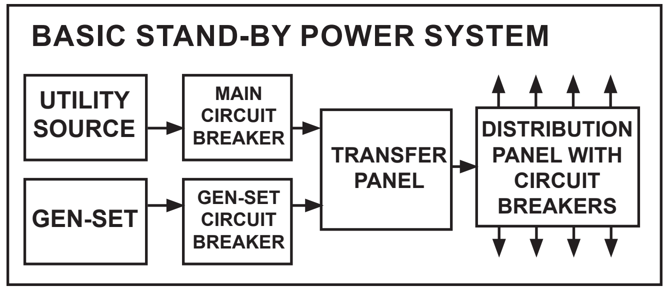
Switchgear can be as simple or complex as you want or can afford. Of course, as complexity increases, so does cost. Balance and a good electrical advisor are the keys here. The diagrams at right illustrate basic configurations for prime power and stand-by systems.

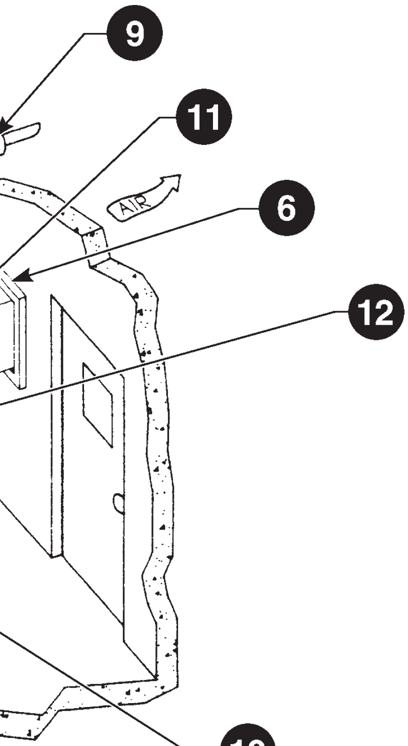
All generator systems require a circuit breaker **(2)** and a distribution panel **(3)**. The ciruit breaker protects the generator set from short circuit and unbalanced electrical loads. The distribution panel divides and routes the connected loads and includes circuit breakers to protect these loads.

Stand-by systems also require a main circuit breaker between the utility source and the transfer panel **(4)**. The transfer panel switches power from the utility to the gen-set and back so that both aren't on at the same time.

Auto-start, auto-transfer systems are available but are costly. Your supplier or contractor can help you determine what you will need.




This diagram shows a stand-by installation and includes optional equipment. Many installations are not nearly as complex as this one. Let your dealer help you design a system to meet your requirements and budget.

1. DC Control Panel
2. Generator AC Circuit Breaker
3. AC Distribution Panel
4. Transfer Panel (stand-by only)
5. Cooling Air Inlet
6. Air Outlet
7. Exhaust System
8. Exhaust Flex
9. Exhaust Thimble
10. Fuel Tank
11. Cooling Air Outlet Duct
12. DC Battery
13. DC Battery Charger (stand-by only)

## INSTALLATION

Our first recommendation is: Let a licensed contractor do it. He has the tools, the know-how and an understanding of governing regulations and local codes. His expertise will save you money in the long run.

If you are a dedicated do-it-your-selfer, do your homework before tackling the job and obtain the proper permits required by your local jurisdiction. While all gen-sets have some basic requirements, each brand and model has special idiosyncrasies. Also, it is extremely important to have all relative codebooks for reference and to adhere to them strictly. Most important of all, your system must be inspected before getting it up and running.

## LOCATION

Where do you put it? Wherever you choose, be sure the following elements are present:

- Air inlet for combustion and engine cooling **(5)**.
- Outlets for exhaust **(7, 8, 9)** and hot cooling air **(6)**.
- Fuel, battery and AC electrical connections.
- Rigid, level mounting platforms (many sets are already mounted on a steel skid base).
- Open accessibility for easy service.
- Isolation from living space. Keep noise and exhaust away from occupied areas.
- Space and equipment to extinguish a fire.
- Minimize the possibility of fire danger.

Remember, gen-sets move on their vibration mounts. Allow clearance to compensate and use flex-joints on all lines and connections.

## EXHAUST SYSTEMS

The exhaust system **(7)** may need to be covered with insulated material to prevent fire from contact with combustible materials, to reduce the heat radiated from the exhaust and to ensure personal safety. Some insulation materials are best left to professionals with the proper equipment. Keep the piping away from combustible materials including walls.

A seamless, stainless steel flexible joint **(8)** must be used between the generator set and the exhaust system to prevent metal fatigue.

Don't use the exhaust manifold to support the exhaust system, the weight can cause manifold failure. Exhaust pipe hangers are readily available.

## FUEL SYSTEM

Extreme care should be taken in designing and installing the fuel system to prevent fire danger. Fuel lines should have as few connections as possible and be routed to prevent damage. Keep lines away from hot engine or exhaust components. The lines should be no smaller than the inlet and outlet on the engine. Support fuel lines with clamps, as needed to help prevent metal fatigue from vibration.

The fuel tank **(10)** should be level with or below the set to prevent siphoning in the event of a line failure. Remember to check the lift capacity of the engine fuel pump and make sure to stay within its limits. If the set is higher, an auxiliary fuel pump may be required. To prevent water ingestion, fuel should be drawn out of the top of the tank with the pick-up extending to no more than two inches from the bottom.

Fuel storage tanks must have leakage protection. Above ground tanks are recommended due to EPA regulations. Check your local codes before installing a tank to make sure it is EPA approved. The safest tanks are double walled with alarms. These alarms are simple and well worth it to prevent a possible fuel spill.

If the tank is mounted above the generator set, use a fuel shut-off valve. This will allow you to work on the fuel system wihout the fuel siphoning out. It will also allow you to cut-off fuel flow in the event of line breakage.

A high quality, fuel/water separator filter should be mounted as close to the generator set as possible.

Because of its explosive nature, gasoline fuel systems have special requirements, see your supplier for complete information.

## AIR

The generator set needs air for combustion and cooling. The engine is cooled by a radiator and an engine fan. The generator is cooled by an internal fan. The room, or space, in which the generator operates should not exceed 100°F. We recommend keeping it under 85°F if possible. All installations require an intake for cool, clean air and an outlet vent for hot air.

Since the size of the space affects the room temperature (the smaller the space the generator runs in, the higher the room temperature is likely to be), smaller spaces may require ducting. Other factors which will affect the room temperature include generator size and the outside air temperature or climate.

In an inside installation,  increasing these vent sizes may cool the room down to acceptable levels. If this doesn't provide sufficient cooling, ducting may be required to ensure "positive" air flow. Stated simply, positive air flow is cool, clean air in – hot air out, as opposed to circulating hot air inside the room.

Generator cooling fans move moisture as well as air. Moist air is corrosive to a genset's copper windings. Make sure air inlets are positioned to minimize moisture intake.

## DC CONTROL PANELS AND BATTERY

Mount your control panel wherever it is most convenient. Mounting it on a wall isolates it from engine vibration. Dual remote panels give you the added convenience of operating your set from two locations. Wire harness plug-ins are available on some sets. Simply plug one end of the harness into the set and the other into the control panel. Harness extensions are also available.

Protect the panel from moisture. Route the harness in dry, protected wire raceways.

Check your manufacturer's recommendation for battery and battery cable sizes. Stand-by sets often have a battery charger which keeps the starting battery fully charged and assures quick emergency starting.

## AC CONNECTIONS

Connecting the generator to your electrical distribution system is a job for a qualified, licensed and bonded electrician who knows local building codes.

## BEFORE STARTING UP

Once you are finished with the installation, you should call your supplier or electrician again. Arrange to have him come and inspect the work and start your set. He will be able to catch any mistakes that may have been made and either fix them for you or tell you how to do it yourself. 30% to 40% of all generator problems can be attributed to installation problems that weren't caught because no one did a proper pre-start inspection. Those numbers prove that the inspection is well worth the time and money spent.

## FOR ADDITIONAL INFORMATION

- Unified Building Code
- NFPA Pamphlets on generator and electrical power systems.
- Emergency/Stand-by Power Systems by Alexander Kusko

# Electrical

## BASE 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.

### 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. Referring 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

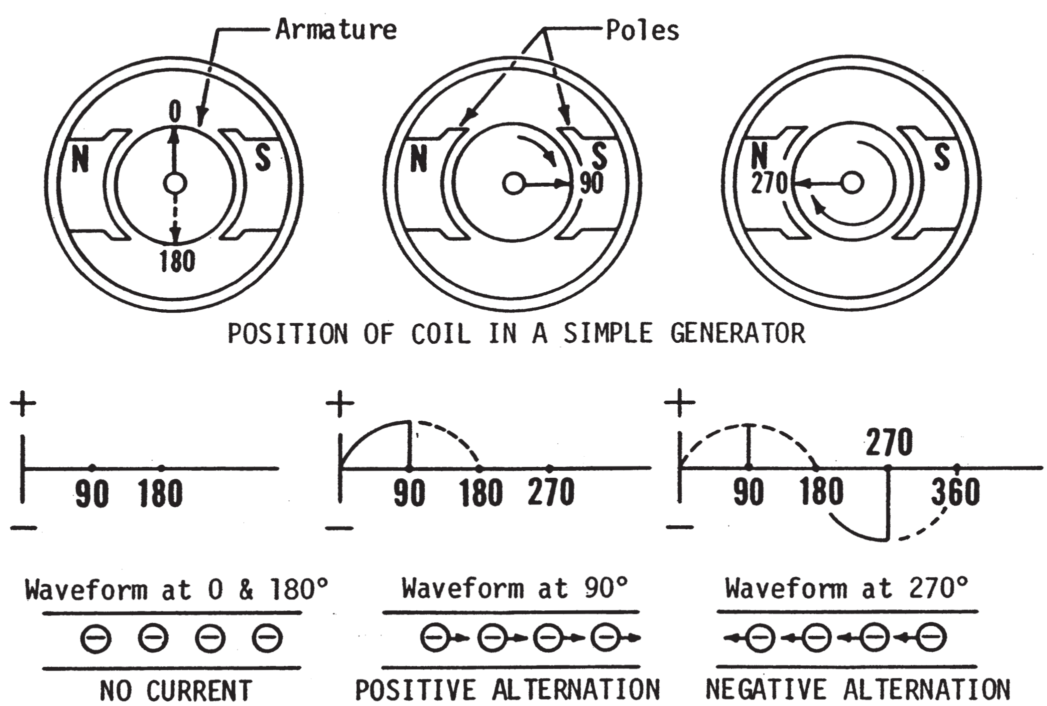



FIGURE 3 - OPERATION OF A SIMPLE GENERATOR

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.

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.

## 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 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 hertz.

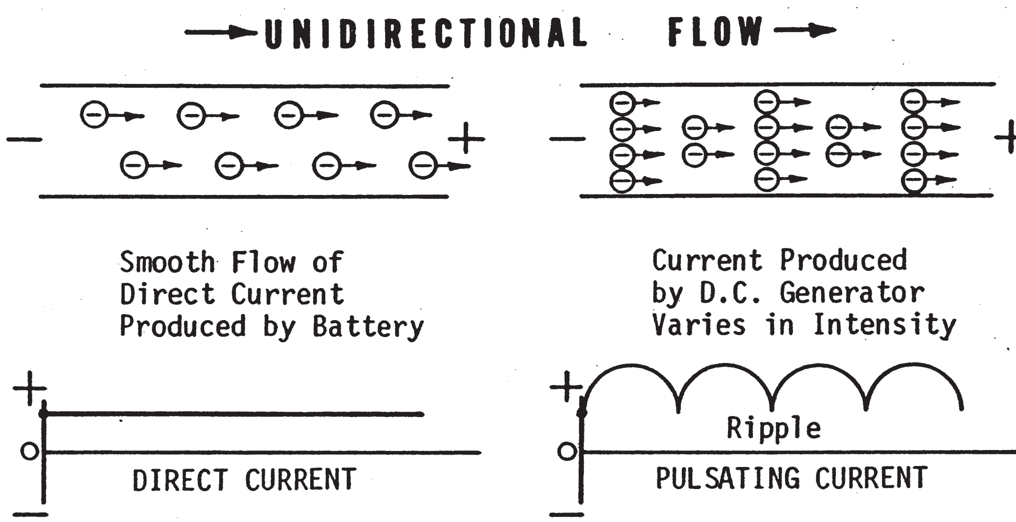



FIGURE 4 - DIRECT CURRENT WAVE FORMS

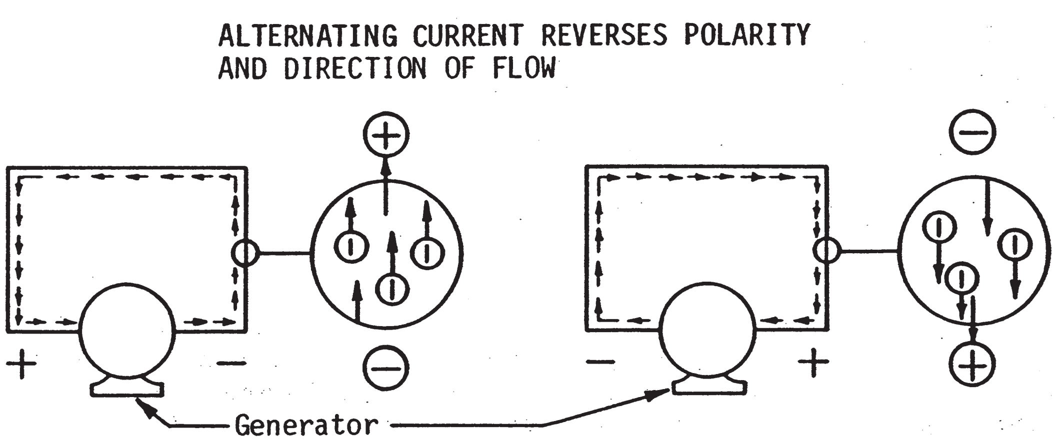



FIGURE 5 - AC REVERSES POLARITY AND DIRECTION OF FLOW

# ELECTRICAL UNITS

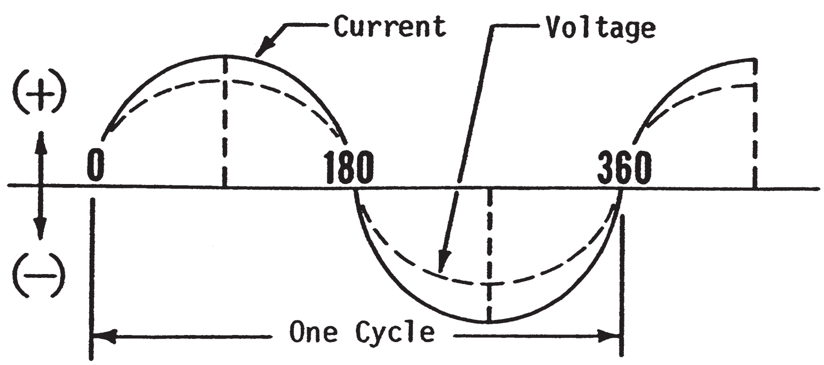



FIGURE 5-A - ALTERNATING CURRENT SINE WAVE

In the study of electricity and electrical circuits, it is necessary to establish definite units to express qualitative values of current flow, voltage (difference in potential) and resistance. The standard electrical units area 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. Relating this to electricity, we can have the same amount of current in this electricity, however it is obvious that the difference in potential or voltage 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 voltage which causes the flow.

## VOLT - UNIT OF ELECTROMOTIVE FORCE (EMF)

The volt is the measurement of 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.

## OHM - UNIT OF RESISTANCE

In all electrical circuits there is a natural resistance or opposition to the flow of electrons. When an electromotive force (emf) 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 physical 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 potential difference (volts) which causes the current to flow.

b) The opposition to current flow or resistance of the circuit

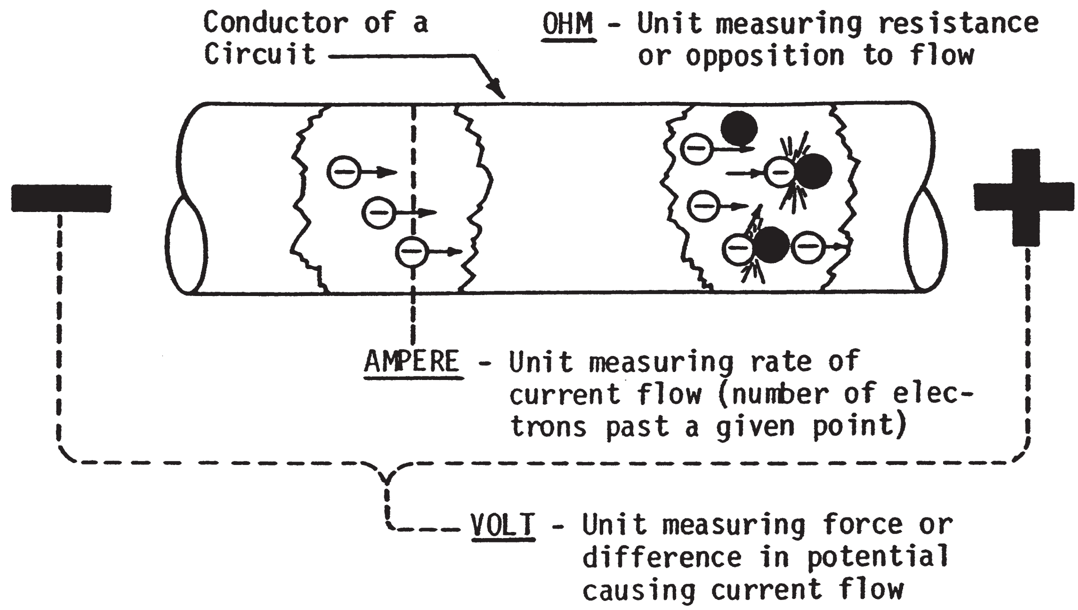



FIGURE 6 - ELETRICAL UNITS

(ohms).

c) The current flow (amperes) which is maintained in the circuit as a result of the voltage applied.

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 x 10 = 50 volts.

The formula may also be arranged to have amperes the unknown factor, for example, Amperes = volts divided by ohms.

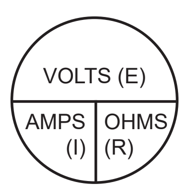
To have ohms the unknown factor, arrange the formula in this manner. Ohms = volts divided by amperes.

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.

## WATTS - UNITS OF POWER

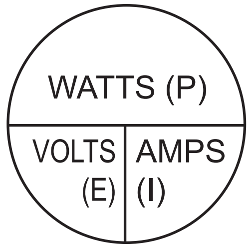
We measure electric power in watts. One watt is equal to a current of one ampere driven by an emf of one volt. For the larger blocks of power we use the term kilowatt for one thousand watts. There is a definite relationship between electric power and mechanical power. One horse power equals seven hundred 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

| MEASURING UNIT - SYMBOL | EQUATIONS | RELATION OF UNITS* |
|---|---|---|
| CURRENT FLOW - AMPERES = I<br>DIFFERENCE ON POTENTIAL - VOLTS = E<br>RESISTANCE - OHMS = R | AMPERES = $\frac{\text{VOLTS}}{\text{OHMS}}$<br>VOLTS = AMPERES X OHMS<br>OHMS= $\frac{\text{VOLTS}}{\text{AMPERES}}$ |  |
| CURRENT FLOW IN A CIRCUIT IS DIRECTLY PROPORTIONAL TO THE VOLTAGE AND INVERSELY PROPORTIONAL TO THE RESISTANCE. | | |

* When two values are known, cover the unknown to obtain the formula.

## WATTS - THE MEASURING UNIT OF ELECTRICAL POWER




EQUATIONS

$$\text{WATTS} = \text{VOLTS} \times \text{AMPERES}$$

$$\text{AMPERES} = \frac{\text{WATTS}}{\text{VOLTS}}$$

$$\text{VOLTS} = \frac{\text{WATTS}}{\text{AMPERES}}$$

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.

### 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.

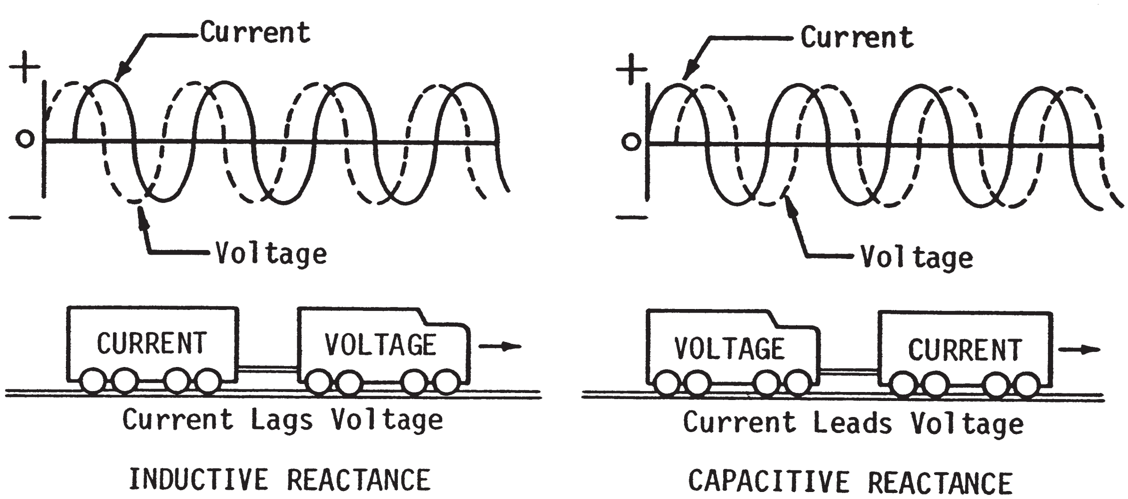



FIGURE 9 - REACTANCE SINE WAVES

# 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.

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 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.

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˚

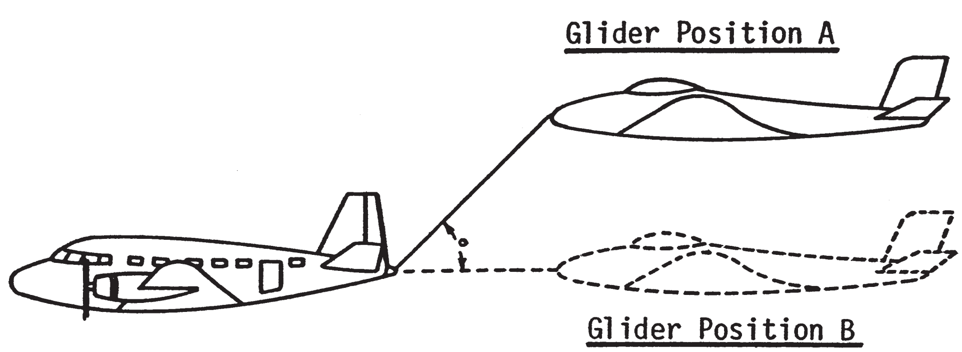



FIGURE 10 - MECHANICAL WORK - POWER FACTOR

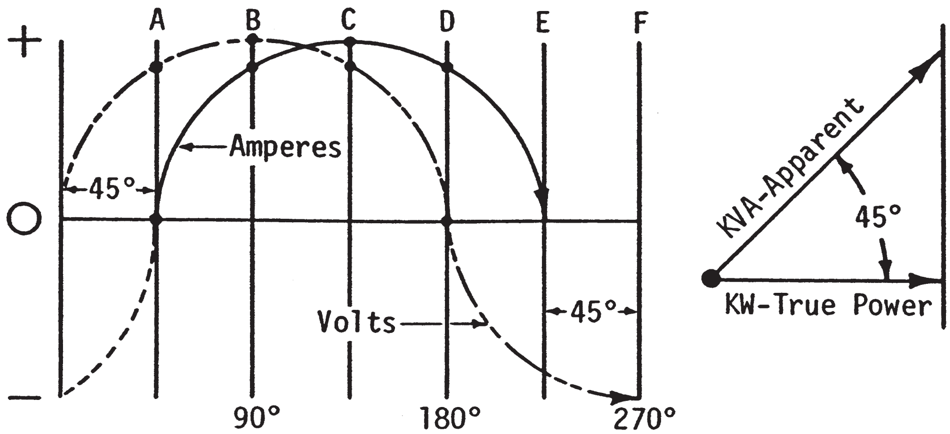



FIGURE 10-A - POWER FACTOR DETERMINED BY DEGREE VOLTS "OUT OF PHASE" WITH AMPERES

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 a single phase AC generator is stated at "unity" power factor for pure resistance type loads. This rating is also frequently stated at .8 power factor for 3 phase generators 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.

# AN APPROACH TO PRACTICAL GENERATORS

Practical AC generators are of the rotating field type. The magnetic field of the rotating field poles is generated by many turns of wire which are supplied by direct electrical connection to the exciter armature (in brushless generators).

The stator, or armature, is constructed of stacked laminations with many slots in which the coils of wire lay. Since a single turn of wire could not be long enough to generate the voltages required, many turns are wound together and distributed in the slots in such a manner that the voltages generated are added together by connecting the coils in series. In order to generate voltages in various phase relationships, the wires in a given section of the armature are grouped together for each phase as shown in figure 3 and figure 4 for single phase and three phase respectively.

All of the possible reasons for the distribution of coils among several slots could not be covered here, nor can the effects of this distribution be discussed completely. However, the shape and value of the output voltage wave depends upon this distribution.

Single-phase and three-phase generators.

So far we have been discussing the single phase generator, that is, a generator with one winding. It may have two or more groups of coils, but it is still single phase if the voltages across the two groups of coils reach their peak at the same time.

Some generators have two windings of which one reaches its peak at the time the other reaches zero. This is a two phase generator. There are very few applications for a two phase systems. Therefore, this brief note will be all of the discussion on this type.

Of the systems we will cover, the one using three windings is most common. These three windings are so placed that three separate voltages are generated. This is called a three-phase generator. The three voltages are equal in value and 120 electrical degrees apart as shown in figure 5. The three windings may be connected in a triangle as in figure 6. This is called a Delta (Δ) connection, or they may be connected in a Wye (Y) as shown in figure 7, with one end of each winding connected. The three-phase system makes more effective use of the iron and copper than a single-phase system, to the extent that in most diesel engine driven generator sets, a single-phase generator will weigh more than a three-phase generator of the same output rating.

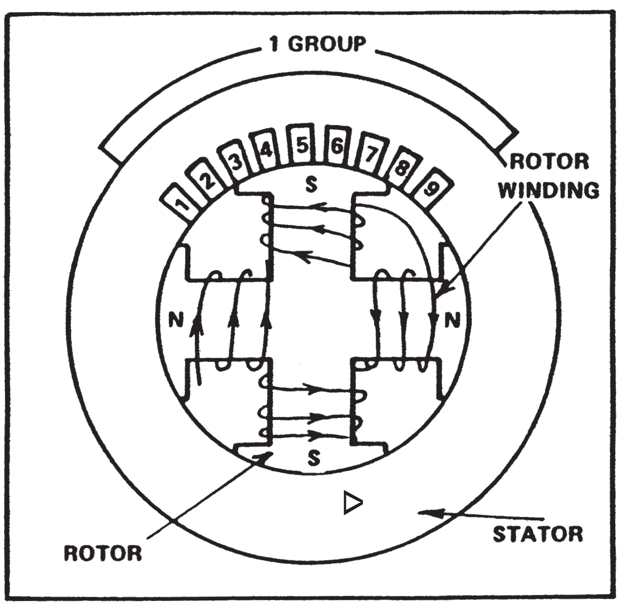



Figure 3 - Single phase grouping

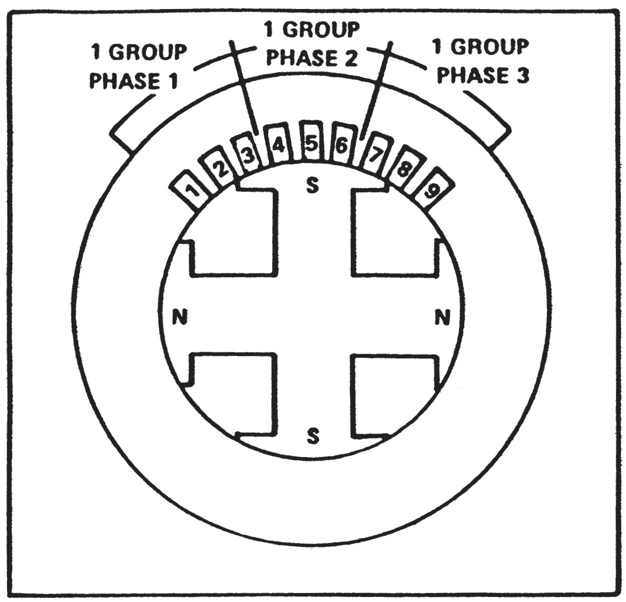



Figure 4 - Three phase grouping

FIGURE 10-A - MECHANICAL WORK - POWER FACTOR

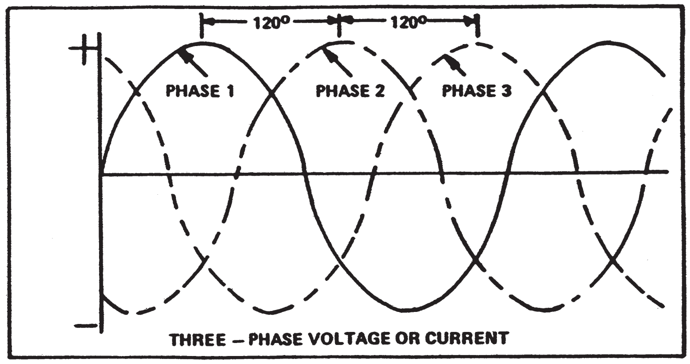



Figure 5 - Three-phase voltage or current

Generally the Wye connection is used in preference to the Delta connection because the neutral can be grounded and also to prevent circulating current which can occur in the Delta connection. Delta connections are used in preference to Wye connections when you want 240 volts three-phase and also 120/208 volts single-phase.

If the central or neutral point of a Wye connection is connected to a line, the circuit becomes a three-phase, four wire system. The three-phase, four wire Wye connection shown below in figure 8 gives 120/208 volts, and accommodates both lights and motors, without the use of lighting transformers. This connection is commonly used for low-voltage networks.

In a three-phase system if the voltage is mentioned without any reference to whether a Delta or Wye system is used or, in a Wye system, whether line-to-line or line-to-neutral voltage is meant, the reference is almost always to be taken to mean the line-to-line voltage.

You are advised to note that in the Delta connection the line-line voltage = phase voltage. In the Wye connection line-line voltage = phase voltage x $\sqrt{3}$ or (1.732 x phase voltage).

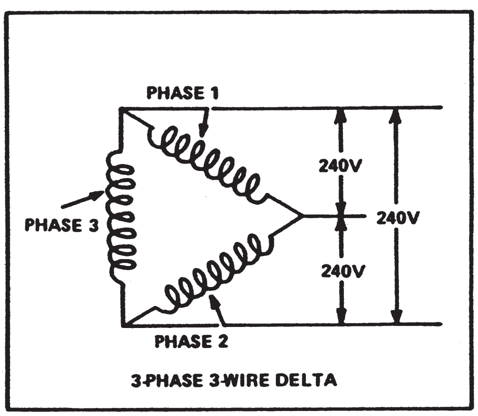



Figure 6 - 3-phase 3-wire delta system

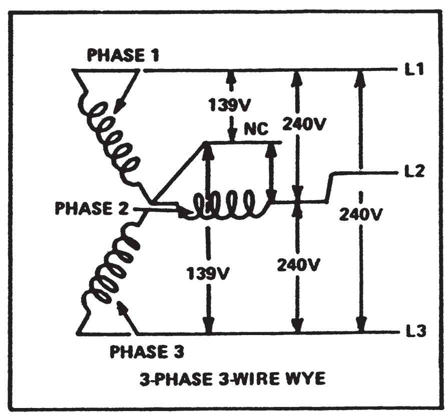



Figure 7 - 3-phase 3-wire wye system

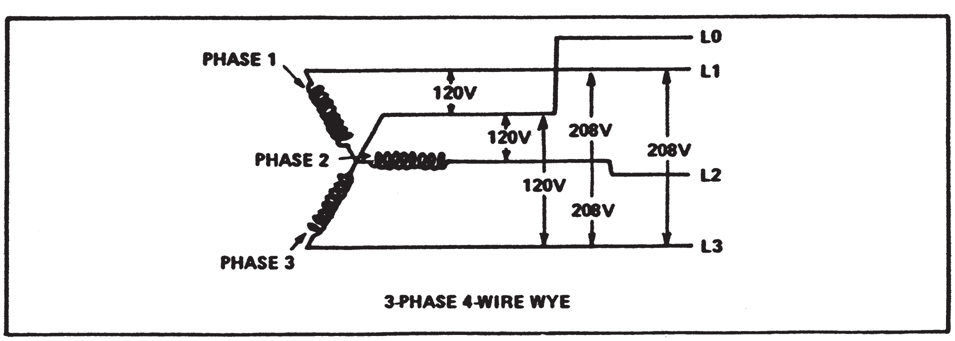



Figure 8 - 3-phase 4-wire wye system

# Principles of Generator Operation

Through residual magnetism of the exciter stator or main rotor, the generator produces the start voltage to fire up the automatic voltage regulator, (AVR). AC from the main stator is fed to and sensed by the AVR. Which in turn supplies DC to the excitor stator. During no load operation this is around 8 to 12 vdc.

This magnetizes the exciter stator............

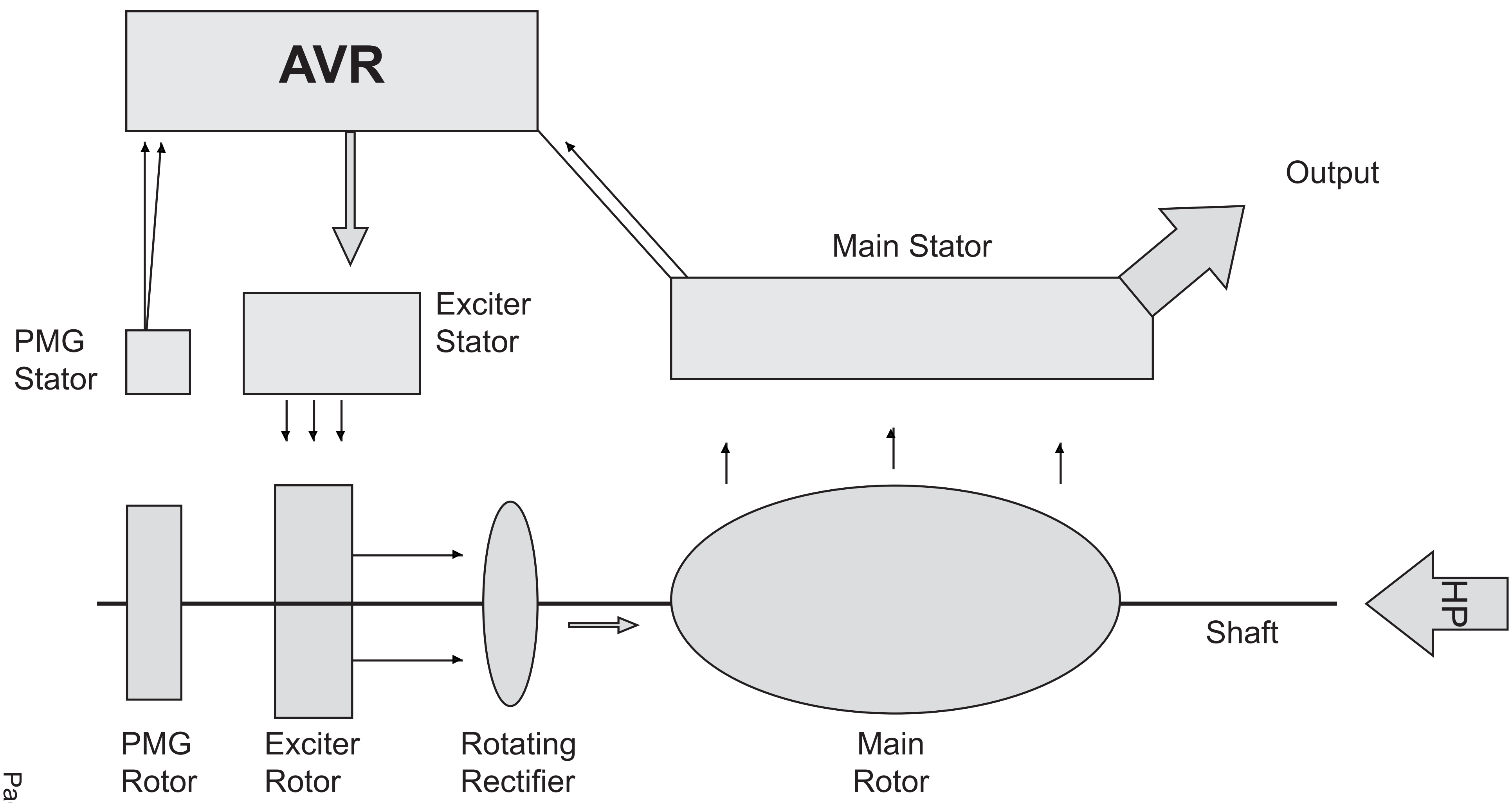
The exciter rotor spins inside the exciter stator field breaking the lines of flux, thus absorbing as AC. Then the AC is fed through a rectifier system to convert to DC............

This DC is then fed up the shaft to the main rotor, magnetizing the rotor.......

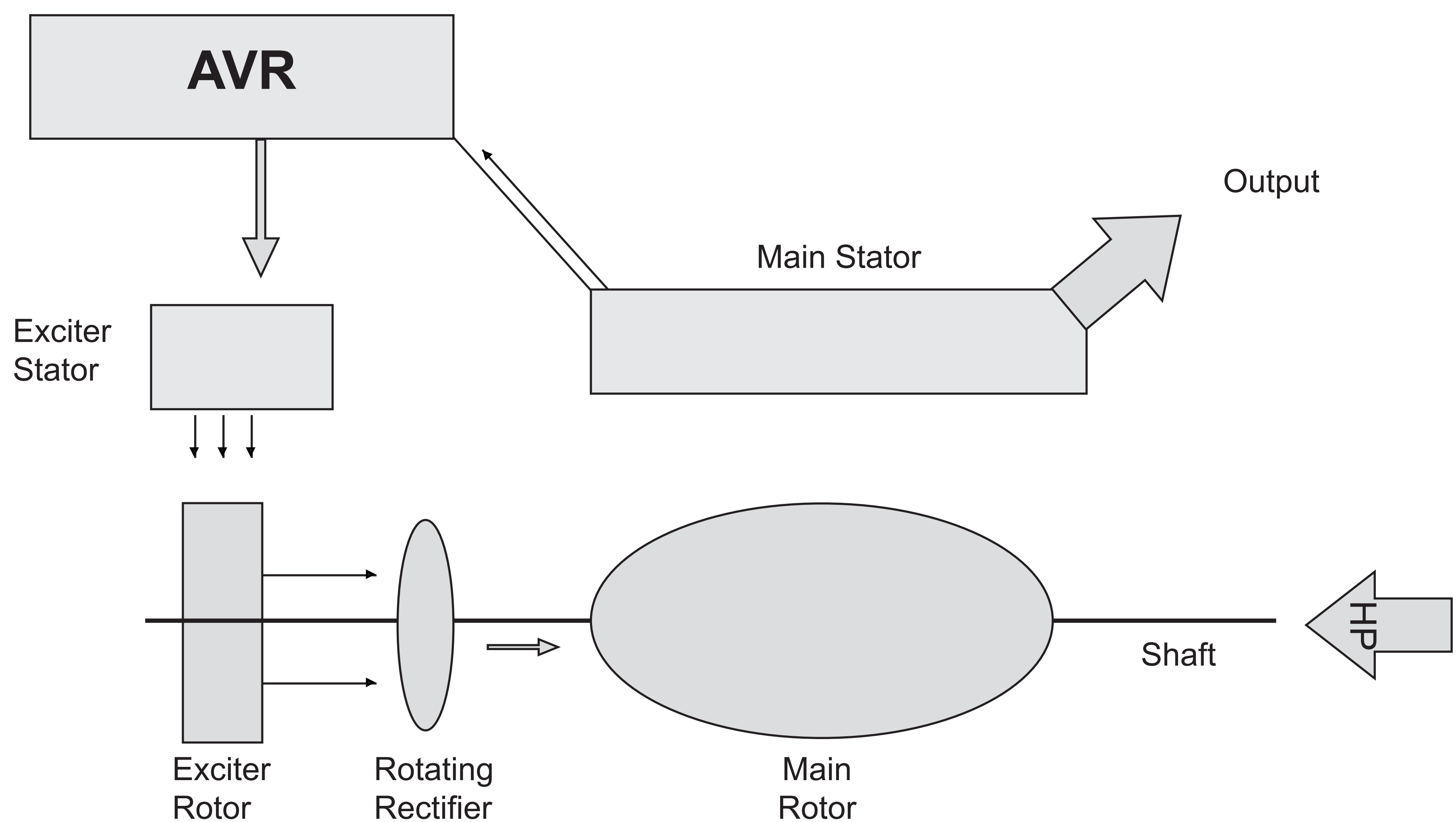
And the main stator absorbing the lines of flux, produces AC regulated by the AVR to the proper output.

When a Permanent Magnet Generator (PMG or W-Series generator), is used, the difference in the operating system is the AVR gets its power from the PMG, not the generator stator. Only the sensing for the AVR comes from the generator stator. This design creates better voltage control for motor loads, SCR loads, and provides 300% short circuit protection.

# Principle of Generator Operation



# Principle of Generator Operation



# Generator-Drive Engines

## FREQUENCY

Drive engines for AC generators must run at a speed that generates the proper electrical frequency. The speed at which an engine runs to produce the desired output frequency is the **synchronous speed.**

Common synchronous speeds for utility loads are:

| Engine Speed | Generator Poles | Frequency |
|---|---|---|
| 3600 RPM | 2 poles | 60 Hz |
| 3000 RPM | 2 poles | 50 Hz |
| 1800 RPM | 4 poles | 60 Hz |
| 1500 RPM | 4 poles | 50 Hz |
| 1200 RPM | 6 poles | 60 Hz |

The synchronous speeds for aircraft support diesel generators are:

| Engine Speed | Generator Poles | Frequency |
|---|---|---|
| 3000 RPM | 16 poles | 400 Hz |
| 2400 RPM | 20 poles | 400 Hz |
| 2000 RPM | 24 poles | 400 Hz |
| 1846 RPM | 26 poles | 400 Hz |

## GOVERNOR DROOP

Droop is the speed change when an engine goes from full load to no load at wide open throttle. Lugger engines are set with a maximum governer droop of 5% at 1800 RPM, and 7% at 1500 RPM. The formula for droop (%) is:

$$\frac{(\text{No Load RPM} - \text{Full Load RPM}) \times 100}{\text{Full Load RPM}}$$

At 5% droop, an 1800 RPM generator-driven engine at a full load speed of 1800 RPM would go to 1890 RPM at no load. This falls within the normal frequency band of 60 Hz to 63 Hz, which is acceptable for pumps, fans, motors, general lighting and utility power.

## FREQUENCY REGULATION

Frequency critical circuits must have an engine that runs at constant speed. This cannot be achieved with the standard mechanical governors on the generator drive engines. A “zero droop” or “isochronous” governor maintains a constant engine speed at any load. Isochronous operation on a Lugger diesel engine requires a fuel injection pump with a customer provided add-on electronic governor or an electronically controlled engine.

Frequency regulation is a result of the engine governor droop. Adjusting frequency requires an engine governor adjustment. Electrical specifications always specify frequency regulation.

## GOVERNOR STABILITY

Stability is determined by how well an engine’s governor maintains a constant speed with a steady load. The fluctuation with mechanical droop governors is ±0.5% or about ±8 RPM. Isochronous governor systems should provide a fluctuation of ±0.25% or less.

Mechanically governed generator-driven engines may surge when governor droop adjustment is less than 5% @ 1800 rpm (7% @ 1500 rpm). Governor stability is affected by the governor droop adjustment. Adjusting a mechanical governor to reduce droop will make the governor less stable throughout the operating range. This reduction in stability can cause “hunting” or “surging” of the engine.

Part load operation also allows unburned fuel to gather in the engine exhaust and lube systems. This type of operation can result in unsightly leakage from the exhaust system, as well as increased maintenance costs. An oversized engine will more likely have these problems. A generator set operates best from 50% to 90% of full rated load. Long term operation at less then 30% of full rated load is not recommended.

## VOLTAGE REGULATORS

External voltage regulators control the output voltage of the generator by controlling the field excitation current. Internally regulated generators are used for special purpose applications and are not adjustable.

The simplest manual and mechanical regulators use rheostats (variable resistors) to adjust the field excitation current to the generator. Systems with little or no variation in load, or systems that don’t require close voltage regulation, may use this type of voltage regulation. Manual and mechanical regulators are inexpensive, but have unacceptable performance for most electrical systems. Mechanical regulators can hold the voltage regulation to

±4%. No regulation is available with manual control.

Transistorized and Silicon Controlled Rectifier (SCR) voltage regulators provide analog control of the field current. Variations in load are sensed by the regulator which adjusts the field excitation current to regulate voltage.

Digital or microprocessor controlled regulators sense engine and generator operating conditions, and make appropriate adjustments in field current and voltage based on logic programmed into the microprocessor.

Any voltage regulator (transistorized, SCR or digital) that can adjust the field current in response to a load change is called an Automatic Voltage Regulator or AVR. AVR's can maintain the voltage within ±2% of nominal voltage, and some hold to ±0.5% or better.

## TRANSIENT RESPONSE

When load is applied to an AC generator set, the engine speed drops until the governor can recover. The time it takes to recover the voltage and frequency to the normal bandwidth is called, recovery time. Recovery times are influenced by many factors including engine, generator, and voltage regulator design.

The operational requirements of the electrical system are determined by the type of load on the system. Light bulbs are not affected by voltage or frequency changes other than a change in brightness (brown-out) when the voltage drops. However, when electric motors run below rated frequency, they overheat. If the voltage drops too far, motor controller relays may drop out and knock the motor off line.

AVR's are designed to drop voltage when a sudden load is applied. This drop, called voltage dip, reduces the load on the engine and allows for quick recovery times. Dropping the voltage also reduces the load on the motors and reduces motor heating problems. Voltage dips of up to 35% are acceptable for most utility load systems. Voltage sensitive circuits may tolerate voltage dips of up to 20%.

To improve the recovery time, AVR's for diesel generator sets may incorporate a Volts/Hz adjustment that drops voltage and frequency while the engine is picking up the load. Loss of frequency regulation for a few seconds does not cause problems for typical utility loads. Volts/Hz regulators designed for turbocharged engines have a delay to allow for turbocharger recovery before applying the load. This gives quicker overall response than loading the engine before the turbocharger can respond to the load change. AVR's designed for naturally aspirated engines do not have this delay feature.

The use of AVR's has improved the response characteristics of generator sets so that engines with high BMEP ratings can carry larger electrical loads. With modern AVR's, which incorporate Volts/Hz adjustment, the Lugger diesel prime mover engines can be expected to provide response times in the 4-second to 5-second range when going from no load to full load with a maximum voltage dip of 35%. Better performance can be achieved by lowering generator output levels, applying the load in steps or with high performance voltage regulators.

## CYCLIC IRREGULARITY

When the engine firing pulses are spaced further apart than one electrical cycle or 1 Hz, the electrical wave form may be distorted. This can cause problems for certain types of electronic equipment. Cyclic irregularity is most likely when the number of engine cylinders is less than the number of poles in the generator.

## OVERSPEED PROTECTION

Most customers assume a runaway engine to be the cause of overspeed problems in a diesel generator set. This is seldom the case. A runaway engine is unlikely.

A generator set is more likely to overspeed due to the introduction of regenerative power into the electrical bus. This drives the generator as a motor and overspeeds the unit. When this occurs, the engine governor drops the fuel rate to the idle setting. For overspeed protection, the generator set assembler can provide an overspeed trip which would cut off fuel to the engine and shut down the generator. The trip should be set at 15% to 20% above rated engine speed.

## BALANCED THREE-PHASE LOAD

Generators should have the resistive and inductive loads balanced on each phase. A phase imbalance of more than 5% will cause unstable voltage regulation. This problem cannot be corrected with engine or generator adjustments. The distribution circuits should be rearranged until balance can be achieved.

## DC GENERATORS

DC Generators are occasionally used for special purpose equipment or more typically to repower old units. Since there is no frequency in a DC electrical system, it is much simpler to operate in parallel. DC generator drive engines use droop governors and do not need to be synchronized. The load is balanced with field excitation adjustment.

# Start up procedure for Generator Sets

1. Check all electrical connections in generator and panel.
2. Check fuel system and bleed out any air. Make sure supply and return lines are open.
3. Check exhaust system for proper installation

   a. Dry exhaust

   b. Wet exhaust
4. Check engine ventilation system.

   a. Industrial application

   b. Marine application
5. Check for proper fluid levels.

   a. Heat exchanged units, seawater is at pump.

   b. Keel cooled units.

Most keel cooled units will overheat on start up, because of air in the system. This will be indicated by a rise above 200 degrees on the engine temperature. Water pump inlet will be hot and the expansion tank discharge will be cold.

Method to correct this:

1. On a cold engine, fill coolant system slowly. Using vent on side of thermostat housing, vent air out until water flows through vent. Also bleed air from vent on turbo, on turbocharged units.
2. On a hot engine, with engine running, carefully keep adding coolant with the thermostat vent open until engine temperature drops to normal and unit stops taking coolant. Close vent. Be careful of engine burping coolant and air out the filler opening. Also double check turbo vent for air.

   c. Radiator units, coolant should be approximately 1 inch below top of radiator.

6. On some installations, keel coolers are installed in such a manner that the cooler slopes upwards away from the inlet and outlet. In this case it is the responsibility of the boatbuilder to install a bleed screw at the high point of the cooler.
7. Start unit at no load.
8. Check AC output voltage at the generator, for proper output. And make sure the generator output is the proper voltage and phase that is needed by the boat or building.
9. Check AC voltage regulator field voltage.

   a. 10 to 18 volts DC approximately - with no load.
10. If voltage regulator fuse or breaker blows, check wiring and make sure generator is not connected to the load source.
11. If 8, 9, and 10 are okay then check panel meters for proper operation.
12. Then apply load and note operation of equipment for normal events.
13. Fill out paperwork.

# Paralleling Procedure

PRELIMINARY STEPS

Step 1. Start unit no. 1 and record no load AC voltage, hertz, and DC field voltage. Close line circuit breaker to the buss and load. Then record again the load AC voltage, hertz, and voltage regulator DC field voltage in steps of 25% load if possible.

Step 2. Start unit no. 2 and record no load AC voltage, hertz, and DC field voltage

Then check phase rotation to match the buss.

Remove unit no. 1 from the buss and put unit no. 2 on the buss, recording loaded AC voltage, hertz, and voltage regulator DC field voltage. In the same load steps as on first unit.

The purpose of doing the above is to match AC voltage between the units. So when you are done with the settings both units should have the same no load voltage and they should droop the same amount of voltage under the same load conditions. And the same goes for the speed droop. The AC voltage stability on all units should be about the same to minimize cross current at no or light load conditions.

A word on cross current, the voltage regulator should have the paralleling option to provide regulator droop under load conditions, if one units voltage goes up and the other units voltage goes down, reverse the "ct" leads at the regulator to match.

After preliminary adjustments are made you should not have to do them again, unless for some reason the values change. Always record readings and keep, in maintenance log.

SYNCHRONIZATION STEPS

Step 1. With one unit on the buss and carrying the load, start the second unit.

Step 2. Turn on the sync. lights or scope.

Step 3. Observing lights adjust speed of second unit to be slightly faster than the unit on the buss. The lights will go on and off slowly (bright to dark).

Step 3a. With the sync. scope adjust the off line unit's speed so that the scope rotates clockwise slowly.

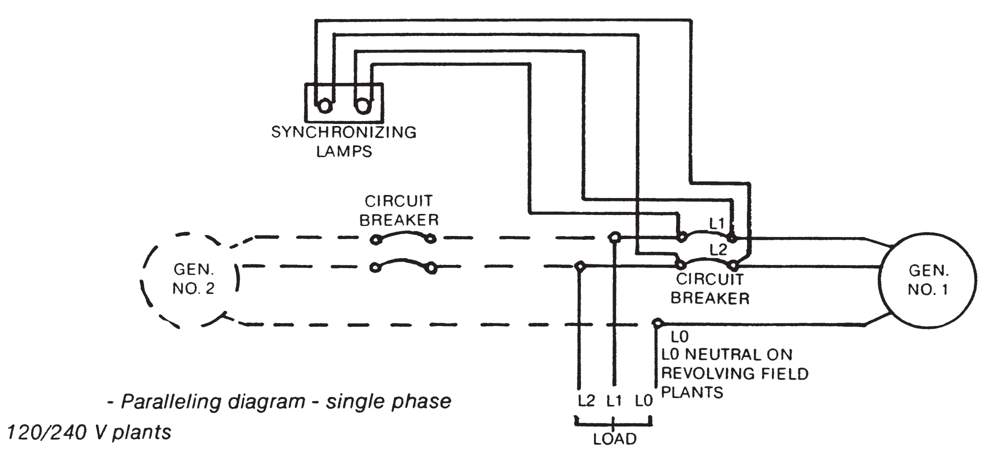
Step 4. At the instant the lights go darkest, close the second unit's circuit breaker to the buss.

Step 4a. With the sync. scope, as it rotates between the 11:00 and 1:00 position instantly close the second units circuit breaker to the buss.

Step 5. At this point you can balance loads by adjusting engine speed. Load imbalance is a function of engine speeds up or down.

NEVER ADJUST VOLTAGE AFTER UNITS ARE IN PARALLEL!!!!!!!!!!

PARALLELING PROCEDURE MANUAL,
LIGHTS OR SCOPE




Paralleling diagram - single phase

120/240 V plants

# Engine Power Ratings

An engine is given a certain power rating by the manufacturer according to the type of service in which the engine will be used. The objective is to limit the maximum power output so that desired engine life will be achieved. For example, a prime power rating is higher than a continuous rating but lower than a standby rating.

Engine life expectancy is usually expressed in terms of engine operating hours before its first major overhaul. In some cases, engine life in terms of years of service may be more significant. Life expectancy for a heavy-duty diesel engine in either continuous or prime power service will average 10,000 hours, or more, provided the engine is properly applied and maintained.. The same engine with a higher rating would have a shorter life expectancy.

An engine for standby service might operate an average of only 100 hours per year. So it would be ridiculous to rate its power capacity low enough to achieve a 10,000-hour life because it would be in service 100 years before it needed an overhaul. Therefore, an engine for standby service can be rated at a much higher power level. Even if it's operating life is only 2,000 hours, it could be 20 years before its first major overhaul.

## RATING EXAMPLES

As an example of different ratings for the same engine, assume that a certain engine is capable of producing 750 HP at 1800 RPM with factory-specified fuel input. If this engine is to be used in continuous service, driving a pump or generator at a constant power level day in and day out, it might be rated at only 465 HP to achieve the desired life expectancy. This would be an example of a continuous rating.

If the engine drives a generator continuously 24 hours a day 365 days a year, but its load varies with fluctuations in demand and averages not more than 465 HP, it might be rated at 560 HP to achieve the desired life expectancy. This would be an example of a "prime power" rating.

If the engine drives the generator in standby service, where it operates an average of about 100 hours per year, it might be rated at 750 HP allowable maximum output. This would be an example of a standby rating. At this rating it would have an adequate life expectancy in terms of years of service.

It should be understood that 750 is not the maximum power of which the engine is capable. It is the power capability with a factory-specified fuel input related to the type of service. The maximum horsepower that can be demonstrated at the factory is substantially in excess of 750 HP.

In some diesel engines, the proper size of injector is installed to match the power rating to the particular type of service and desired engine life. Other types of engines might depend on the governor's load-limiting adjustment to achieve the same purpose. A drawback of depending on the load-limiting adjustment is that it could be tampered with to raise the power limit and thereby degrade engine life and increase smoke and emissions.

In selecting an engine for a standby application, it is obvious from the foregoing that it would be uneconomical to base your selection on a continuous or prime power rating. You would be paying for an engine that is much larger and has much greater life expectancy than you need. Moreover, such an oversize engine would suffer greater efficiency loss at part-load, which is the load condition in which a standby electric set is likely to operate most of the time.

While there is general agreement among engine manufacturers on the definition of continuous-duty rating, unfortunately there are no industry standards for prime power or standby ratings, and each manufacturer establishes his own rating definition. This creates some confusion in making a true comparison of one manufacturer's definition with another's. However, the following should clear up this confusion.

## CONTINUOUS-DUTY RATING

The engine manufacturer establishes a continuous-duty rating for each basic engine model, which indicates the amount of horsepower the engine is allowed to deliver when operated 24 hours a day, 365 days a year, while powering a constant fixed load, at a constant fixed operating RPM. Generally, for most engine manufacturers, the same basic engine models are used to power mechanical equipment as are used to drive electric generators. Thus, the continuous-duty horsepower rating is the same no matter what type of equipment the engine drives. The 1800 RPM speed of Lugger engines affords long life and reliable operation because it is the same or less than the industrial continuous rated speed of each engine.

When applied to heavy-duty diesel engines, the continuous-duty rating defines a power output and speed at which the engine can be operated steadily with a life expectancy of 10,000 hours, or more. The desired life can be expected if the rated power and speed are never exceeded.

In electric-set applications, a constant fixed load is the exception rather than the rule. Therefore, in the interest of proper and efficient applications of engines to power electric sets, it is necessary to recognize two other types of ratings that is the majority of electric-set applications. These ratings are called prime power and standby power.

## PRIME POWER RATING

“Prime power” is the rating for applications in which the electric-set is the sole or normal power source, and in which optimum engine life is to be expected. Examples are small municipalities; remote industrial construction, mining or power installations; and commercial or industrial plants. In prime power application, the electric-set might be operated steadily, day in and day out, but its load varies throughout the day. The prime power rating is somewhat higher than a continuous-duty rating to take advantage of the fact that the load is variable. The prime power rating assures that the measured average output over a 24-hour period of operation does not exceed the industrial continuous rating of the engine.

The average output is measured in kilowatt-hours, based on a 24-hour operating period. A kilowatt demand meter can be used to measure the average demand, or the 24-hour average fuel consumption can be measured and converted to kilowatt-hours. If the average horsepower output over a 24-hour operation period exceeds the industrial continuous horsepower rating, the engine life will be decreased proportionately.

## STANDBY RATING

In recognition of the limited running time experienced in standby service, the standby power rating is higher than a prime power rating. The engine should be capable of producing its standby rated horsepower continuously for the duration of each electric power failure. Thus a “flash” rating would be unacceptable for standby service. A flash rating is a rating for a limited period of time such as 5 seconds, 5 minutes, 2 hour, etc. The word “continuously” as used here in the standby context, should not be associated with the continuous-duty rating because continuous-duty ratings and standby ratings are meant for two entirely different applications.

Occasionally, a term such as “standby continuous rating” is seen. Such terminology is confusing and can be misleading because it combines elements of two different ratings. If the term “standby continuous rating” merely means a standby power output that can be produced continuously for the duration of the electric power failure, then it is the same as “standby rating.”

In summary, there are three distinct ratings for engines used to power electric sets:

1. Electric-set continuous rating (same as industrial continuous rating)
2. Prime power rating
3. Standby rating

## RATING BASELINE CONDITIONS

The power output capability of an engine depends on the ambient temperature and atmospheric pressure in the generator room. High air temperature or low air density reduces the maximum power capability of an engine. Therefore, when specifying the required kW capacity of the electric set, also specify the maximum ambient air temperature and the altitude or atmospheric pressure of the site.

Engine power ratings published by engine manufactures are based on operation at some standard, or baseline, temperature and altitude. If the engine will be operated in a different ambient condition, its power capability must be corrected to the actual conditions. That is, a new power rating is calculated based on the numerical relationship of the actual temperature and pressure to the baseline temperature and pressure.

When actual ambient conditions are stated in the specifications, the electric-set supplier will take this into account and make the correction in the engine’s power rating before proposing an engine for the electric set.

Two generally accepted ambient condition baselines are used by manufacturers in rating diesel engines:

| S.A.E. Conditions | Standard Conditions |
|---|---|
| 85˚ | 60˚ |
| 500 ft. above sea level | sea level |

Because the S.A.E. conditions more realistically represent average site conditions, Lugger electric-set engines are rated at this baseline. The Standard Conditions rating applies to marine and other sea level applications but usually must be corrected for the higher temperature found in engine rooms.

# Engine Noise

## SOUND AND NOISE

Sound consists of pressure waves traveling through the air (or water, etc.). Sound pressure waves can be described by their frequency and amplitude. Noise is unwanted sound, usually consisting of many pressure waves at different frequencies and amplitudes.

## FREQUENCY

"Frequency" refers to the number of pressure waves per second. It is usually reported as "Hertz" (Hz), which means cycles per second. The human ear can usually detect frequencies from about 20 Hz to 20,000 Hz.

## AMPLITUDE (DB AND DB(A))

"Amplitude" refers to the pressure level of the sound wave. Since sound pressure variations are extremely small and cover a very wide range, they are usually measured on a logarithmic scale called Decibels (dB), instead of conventional pressure units like psi.

Since the human ear has different sensitivities at different frequencies, a 50 dB sound at 200 Hz would not sound as loud as a 50 dB sound at 2000Hz. For that reason noise measurements are usually reported in dB(A). The "A" refers to a set of weighting factors based on the sensitivity of the human ear at each frequency. There are other weighting systems such as dB(B) and dB(C), but most machinery and vehicle sound regulations are in dB(A).

Zero dB(A) approximately equals the lowest possible pressure wave audible to the human ear at each frequency. Each increase in amplitude of 6 dB represents a doubling of sound pressure level. Using the "A" weighting system, a 50 dB(A) sound at 200 Hz should sound approximately as loud as a 50 dB(A) sound at 2000 Hz.

Sound levels from typical sources are shown in Figure 50-1.

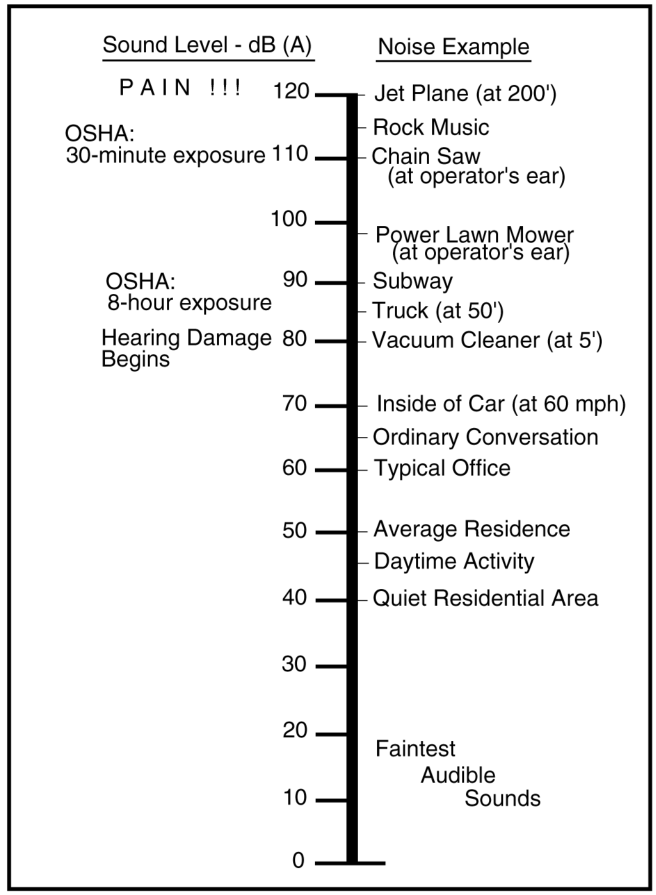



Figure 50-1 - Approximate Sound Levels

## ADDING SOUND LEVELS

Since the Decibel scale is logarithmic, Decibels can't be added directly. When adding sound levels the loudest sound dominates. Adding additional sound sources that are not as loud have relatively little effect. The following chart can be used to add decibel levels from different sources or at different frequencies. Use the chart to add two decibel levels at a time. If you have to add three or more sources, add any two, then add that total to the third, etc.

To use Figure 50-2, first determine the difference between the two values being added. Subtract one value from the other to find the difference, locate the difference on the horizontal (bottom) axis of the chart, draw a straight line up to the curve, then over to the vertical (side) axis of the chart to find out how many decibels to add to the higher of the two original values. For example, if you were adding an 84 dB(A) source to a 90 dB(A) source, the difference would be 90-84=6. From the chart you can see that for a difference of 6 decibels you should add 1 decibel to the highest of the two levels, so you would add 1 dB(A) to 90 dB(A) for a combined level of 91 dB(A) for both sources. If you are adding two equally loud sources, say 90 dB(A) each, the difference would be zero, and you would add 3 dB(A) to 90, for a combined level of 93 dB(A) for both sources.

## DISTANCE EFFECTS

Decibel level drops off rapidly with distance. Exactly how much depends on how much the ground and other close objects reflect or absorb sound. In a free field (no absorption or reflection), sound will drop off by 6 decibels for each doubling of distance from the source. You can use this to estimate the effect of increasing or decreasing the distance to the noise source. For example, a noise source of 90 dB(A) at 7 meters would be about 84 dB(A) at 14 meters, or 96 dB(A) at 3.5 meters.

## "ENGINE NOISE" SOURCES

Several different noise sources contribute to what people sometimes consider "engine noise."

The noise levels reported on the back of each engine performance curve are only the noise radiated directly off the bare engine surfaces. They are averages of several microphones located 1 meter from the engine. They do not include noise from the exhaust system, fan, etc.

Engine surface noise may not be the largest noise source. Exhaust noise is frequently higher, and fan noise can be, in some installations.

Other significant noise sources can include the air intake, drive train, hydraulics, tires, etc.

## NOISE TREATMENT - GENERAL

Noise can be transmitted from any noise-generating component in the form of "air-borne" noise or "structure-borne" noise. Air-borne noise is transmitted directly from the surfaces of the component through the air to the ear. Structure-borne noise is transmitted through the engine mounts or other solid connections to the cab or chassis in the form of vibration, then from there it goes through the air to the ear.

Most noise treatments work on either structure-borne or air-borne noise in one of the following ways:

### SOURCE REDUCTION-

Generating less noise at the source, by specifying quieter engines, transmissions, tires, etc.

### SHIELDING -

A heavy wall that will not vibrate easily, placed between the noise source and the ear, can help block the pressure waves. This is what concrete "noise fences" along highways do.

Heavy, solid, well-damped materials (such as concrete, lead, or heavy rubber) make the best shields.

Lighter shield materials (such as sheet steel) are most effective when used in combination with absorptive material and/or damping.

### ABSORPTION -

Plastic foam, fabric, or other soft porous materials can quiet sound by absorbing some of the sound pressure waves.

Both absorption and shielding are most effective on high-frequency vibrations. That's why when a car with a loud stereo passes your house, you hear only the bass.

### ISOLATION -

Rubber mounts can be used to keep structure-borne noise from being transmitted from the engine or other noise sources to cabs or sheet metal that could transmit the noise to the ear. Any solid connection can transmit structure-borne noise, including throttle levers, exhaust system brackets, etc.

Isolating noise sources (such as engines and mufflers) can be effective. But if the operator is enclosed in a cab, isolating the cab can provide the best results.

### STIFFENING -

When structure-borne or air-borne noise is transmitted to cabs, chassis or shields, resonant vibrations can be excited in sheet metal panels, amplifying the noise. Stiffening panels by adding stamped-in or added-on bases can help detune resonant frequencies and reduce amplitudes.

### DAMPING -

Sometimes resonant vibrations in sheet metal panels can be absorbed by adding layers of damping materials (such as rubber or tar-like substances) to the panels. This is why automotive undercoating makes cars quieter.

### SEPARATION -

Dominant noise sources should be physically separated so they do not add together. For example, if the engine surfaces and the exhaust pipe produce 90 dB(A) each, they will produce 93 dB(A) together. But if the exhaust pipe is routed to the opposite end of a large machine, the noise at either end will be close to 90 dB(A).

## NOISE TREATMENT - SPECIFIC

### NOISE SOURCE IDENTIFICATION

The most important rule in noise treatment is to identify the noisiest component, and concentrate your control efforts on it. Even if you completely eliminate the second or third noisiest source it can't have more than a few dB(A) effect. If the noise goes down 3 dB(A) or more when one source is eliminated, it is larger than all other sources combined. A reduction of 1 or 2 dB(A) may also be significant if there are many sources close in amplitude.

You can identify the primary noise source by temporarily removing or treating each source one at a time. Fan noise is easy to check by removing the fan temporarily. To isolate transmission or drive train noise, disconnect the clutch. To isolate exhaust or intake noise, reroute them away from the machine to check their contribution.

### EXHAUST NOISE

Exhaust noise is the loudest untreated noise source on most applications and is also the easiest to treat. Standard mufflers can reduce exhaust pipe noise by 10-15 dB(A) through absorption. Quieter "residential" mufflers are also available. The best source of muffler performance information is your muffler supplier. The exhaust pipe should direct exhaust flow away from the cab, the operator, and bystanders' ear level.

For ultra-quiet installations it may be necessary to wrap the muffler with high-temperature (ceramic) fabric and a sheet metal cover, to shield and absorb air-borne "skin-noise" from the muffler shell.

The muffler can also transmit structural noise to the cab or frame. Avoid bracketing the muffler or exhaust pipes to the cab or frame if possible. If it's necessary to support the muffler on the cab or frame, isolate the exhaust system using flexible exhaust connectors to break the structural vibration path, or use rubberized exhaust pipe hangers such as used on passenger cars.

### FAN NOISE

Fan noise, due to a large-diameter fan turning at high rpm, can be greater than noise coming from the exhaust pipe or engine compartment. Fan noise can be controlled by following these guidelines:

- Run the fan as slow as possible. Fan tip speeds (fan rpm x circumference) of 12,000 feet per minute or less are recommended for quiet installations. If the fan is running over 16,000 fpm, it may be the loudest noise source on the machine.
- Follow the fan application guidelines in the Cooling Section of this manual to maximize fan efficiency. For the same air flow, an efficient fan can be run slower than an inefficient fan. Large fans at slow rpm are usually quieter than small fans at high rpm for the same air flow.
- Air obstructions cause noise when a fan blade moves past them, particularly on the inlet side. Keep the fan at least 1/2 to 1 blade width back from the radiator and well away from engine obstructions (such as alternator pulleys, hoses, etc.).

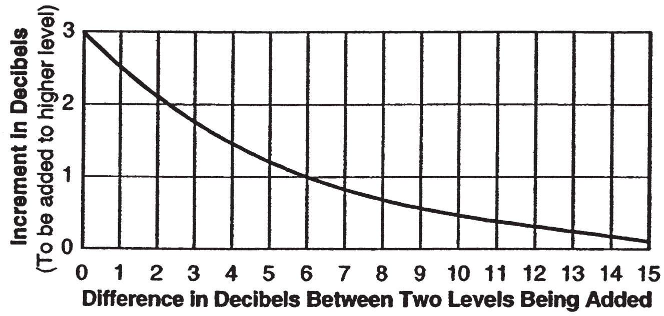



Figure 50-2 - Adding Decibel Levels

- Use shielding and absorption to reduce fan noise at the source.

## ENGINE AIR-BORNE NOISE

Lugger engines are among the quietest in the industry. Generally speaking, engines run somewhat quieter at lower speeds, but other than reducing speed, there is very little you can do to reduce engine surface noise at the source.

The most effective way to treat engine surface noise is by using an enclosure lined with absorptive materials. Sound enclosures work best when as much of the machine as possible is contained within the enclosure. Ideally, the entire machine should be enclosed. This has the added advantage of helping to silence any other noise sources (such as the fan, transmission, etc.) that are also located in the enclosure. (See Figure 50-3).

To provide effective shielding, the enclosure should be sealed as completely as possible, except for air flow openings. Openings for air flow should be generous, but they should be baffled to direct air flow over sound absorbing materials and away from ear level.

The use of a blower fan should be strongly considered to control engine compartment temperatures. Wrapping and shielding of exhaust components will also help. Exhaust should be routed out of the compartment along with the cooling air flow so it does not recirculate in the engine compartment. With blower fans (as shown) it should exit in the front. With suction fans, exhaust should exit in the rear.

With blower fans, the air cleaner inlet can be taken from within the engine compartment. With suction fans, it should be taken from in front of the radiator, but within the front sound shield.

Care must be taken to make sure the sound absorbent materials used can tolerate the high temperatures that can be present in the engine compartment. How high the temperature will be depends on your installation. Exhaust gases or hot components must be kept away from any flammable sound absorbent material. Sound absorbent material should be used cautiously below the engine, particularly if any oil leaks are present. Oil-soaked absorptive material can be combustible.

## ENGINE STRUCTURE-BORNE NOISE

Engines can also transmit structure-borne noise from vibration to frames and cabs. Lugger fully balanced 4-cylinder engines produce significantly less vibration than competitive 4-cylinder engines.

Well-matched rubber engine mounts can also help reduce structural noise transmission. However, poorly matched rubber mounts can be worse than solid mounts. Refer to the Engine Mounting section of this manual for mount design guidelines. Remember that other solid connections such as rigid exhaust pipes will prevent rubber mounts from working properly, and will transmit structure-borne noise themselves.

## AIR INTAKE NOISE

Air intake noise is usually adequately muffled by using a properly sized canister type air cleaner. If you are using a small or “throw-away” type air cleaner and air intake noise is a dominant noise source, consider changing to a canister type.

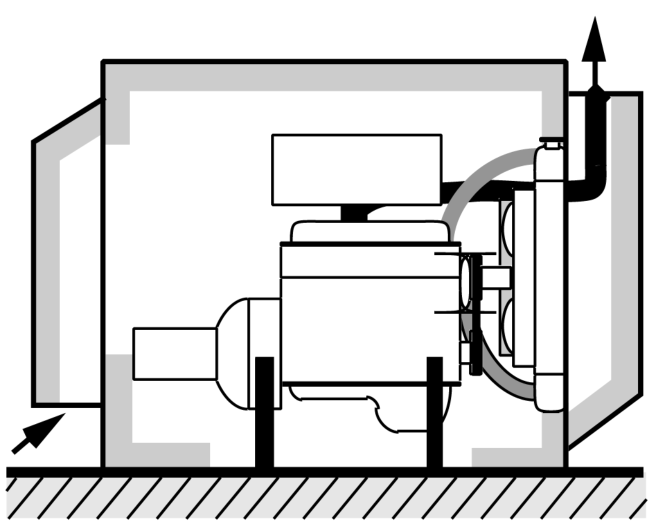


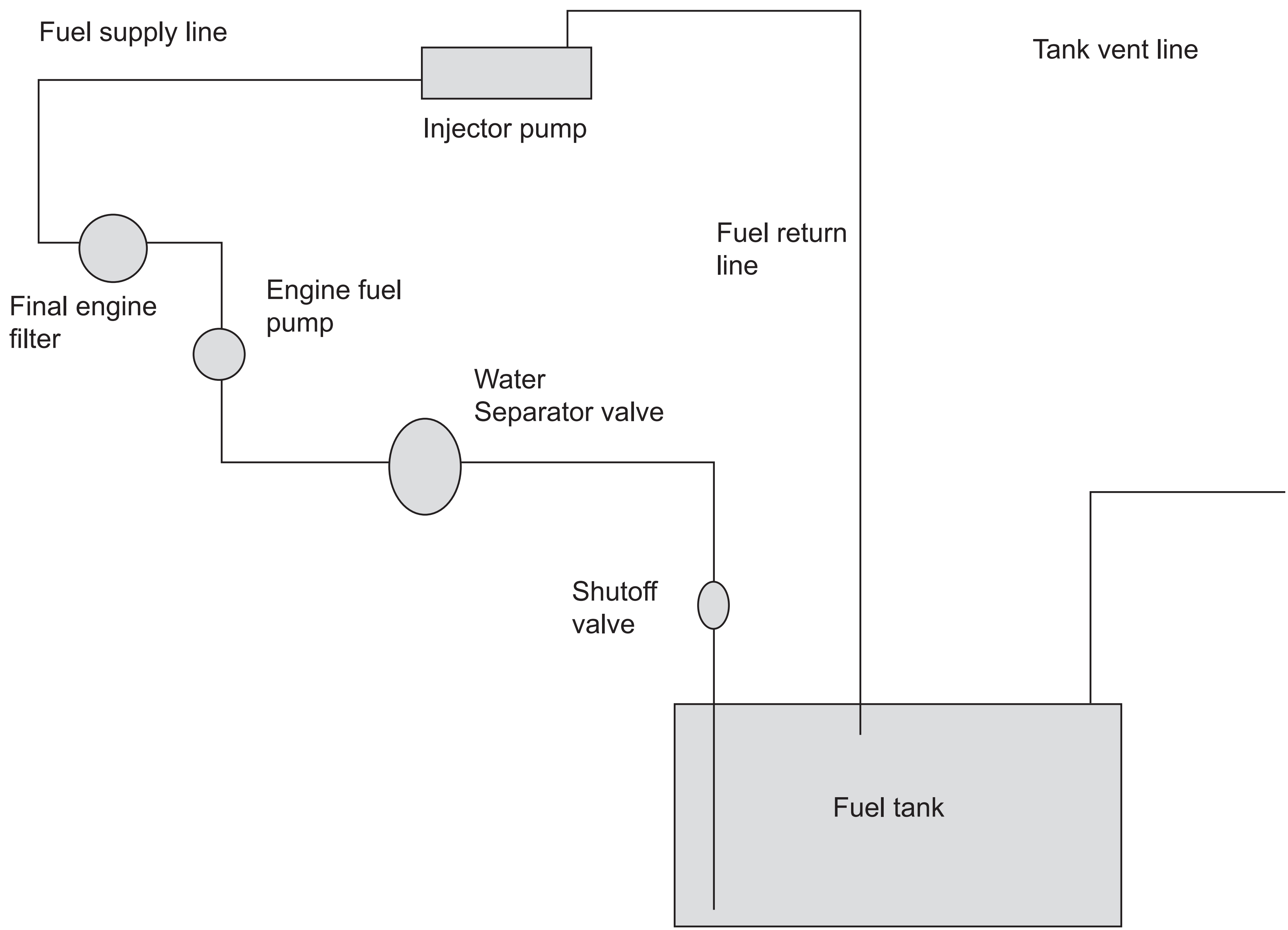
Figure 50-3 - Sound Absorbing Enclosure

# Fuel System Components

1. Fuel tank, vent, and filler pipe
2. Fuel shutoff valve
3. Fuel supply line
4. Primary fuel/water separator filter
5. Engine fuel lift pump
6. Secondary engine fuel filter
7. Fuel injection pump, and injectors
8. Fuel return line

Misc. notes:

- No galvanized fuel tanks
- All fuel hoses used on boats must have U.S. Coast Guard approved “type A” or “type A1” hoses.


Fuel supply line
Injector pump
Tank vent line
Fuel return line
Final engine filter
Engine fuel pump
Water Separator valve
Shutoff valve
Fuel tank

## DIESEL FUEL TERMINOLOGY

- Pour Point: Is 3˚ C (37.4˚ F) above the temperature at which fuel will just flow under its own weight, under test conditions.
- Cloud Point: Is the highest temperature at which the first trace of paraffin wax visibly forms in the fuel. Used as an indicator of when fuel filter blockage might occur.
- Viscosity: A measure of resistance to fluid flow. Is markedly affected by temperature. Also, if temperature is very low, fuel pump lubricity problem could occur.
- Flash Point: Temperature at which fuel ignites with a test flame
- Sulphur Content: Results from crude oil origin, its refining or treatment. Diesel fuels, 1-D and 2-D call for 0.5% or less sulphur content. If higher, must increase oil change frequency. Sulphur content should be as low as possible to avoid premature wear and minimize noxious emissions.
- Ash: In distillate fuel, ash content occurs in elements of the base crude. Can be augmented by contamination from sea water or dusty pipe lines.

FUEL DEFINITIONS

| | |
|---|---|
| • Pour Point | • Flash point |
| • Cloud Point | • Carbon Residue |
| • Viscosity | • Sulfur |
| • Density | • Ash |

Fuel No. 4

## SERVICE TIPS

- Water content:
- Water separators can be used. Must ensure that it does not restrict fuel flow.
- Test on regular basis.
- Additives:
- John Deere anti-gel reduces cloud point (do not use alcohol).
- Biocide will eliminate microbial growth in both storage tank and fuel supply system, preventing buildup in nozzles, lines and F.I. pumps.

## FUEL REQUIREMENTS AND SPECIFICATIONS

- The properties of diesel fuels are defined by ASTM D-975 designation for diesel fuels. These must be controlled to insure good engine operation. Example:
  - Distillation
  - Cetane Number
  - Sulphur Content
  - Cloud Point
- Ambient temperature, engine speed and load all influence the selection of diesel fuel.
- A reputable fuel oil supplier can assure that the fuel received, meets the recommended diesel fuel properties shown including lubricity.
- Cetane number requirements:
  - 45 cetane minimum
  - During winter use a higher cetane rating for better starting.
- Current fuel has sulphur content of 0.5% - 0.29%. New fuel will have 0.05% sulphur
  - Other elements are contained in diesel fuel, but sulphur and water are of greater concern. There is no way to detect the damage contaminated fuel is causing until the damage is done
  - Reduce oil change intervals by one-half when known sulphur content exceeds 0.5%
  - Higher than “normal” sulphur in fuel reacts differently:
    - Variations in ambient humidity, engine temperature, and horsepower ranges, affect the degree of damage
    - Ambient humidity, plus internal engine

FUEL

| Do’s | Don’ts |
|---|---|
| • Maintain Cooling System… Voids Gas | • Use Fuel with More Than 0.5% Sulfur |
| • If Water Separator is Used…Do Not Restrict Fuel Flow | • Use Alcohol to Reduce Cloudpoint |
| • Biocide to Keep Microbe Free | |

Fuel No. 5

condensation rate, promotes damaging sulfuric acid formation.

- Lower horsepower engines suggests less fuel consumption:
  - Less fuel means less sulphur passing through engine.
  - Good preventive maintenance program of oil and filter change intervals, should reduce contamination.

- Low engine operating temperature does not allow the sulphur to get to a gaseous state, so keep the cooling system temperature within range of highest operating efficiency.
- If only low-sulphur fuels are available, add John Deere TY22030 Diesel Fuel Conditioner for lubrication. Low sulphur fuels will have little lubricating properties.

FUEL SPECIFICATIONS

Temperature

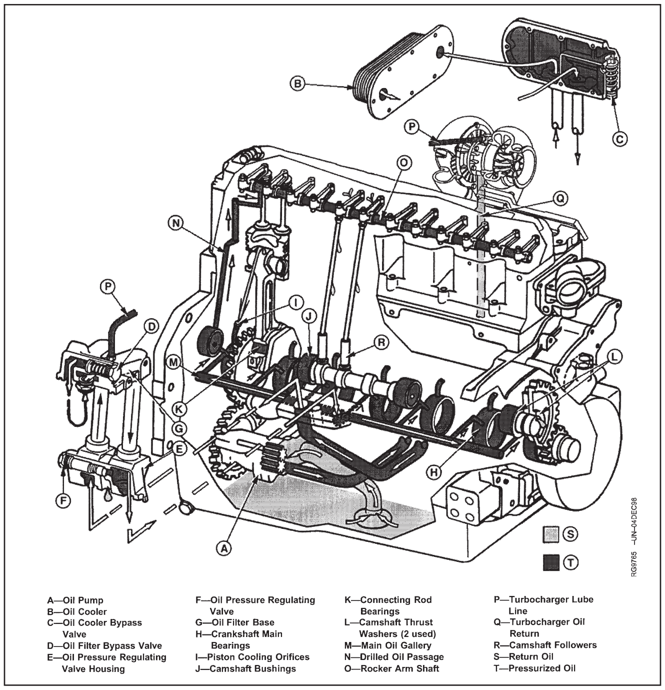
| Below Freezing | Above Freezing |
|---|---|
| Use #1 diesel fuel | Use #2 diesel fuel |

Fuel No. 6

# The Lubrication System

The lubrication system consists of the following:
- Oil pump
- Oil filter
- Pressure regulating valve
- By-pass valve
- Oil cooler

LUBRICATING OIL FUNCTIONS




Lube No.1

- Oils do wear out
- Extended service:
  - Depletes the additives
  - Oxidizes the base oil to form harmful compounds
- Lube oils must:
  - Keep a protective oil film on moving parts
  - Resist high temperatures
  - Prevent corrosion and rusting
  - Prevent ring sticking
  - Prevent sludge formation
  - Flow easily at low temperatures
  - Resist breakdown after prolonged wear
  - Neutralize the affects of acids

ENGINE OIL PERFORMANCE REQUIREMENTS
- Operator's Manual will give type
- Designed to operate at 115˚C (240˚F), higher if equipped with oil cooler

THE

LUBRICATING OIL MUST:

1. Lubricate
2. Cool
3. Seal
4. Clean
5. Protect

Lube No.2

- Oil ratings
  - SAE (Society of Automotive Engineers)
  - API (American Petroleum Institute)
  - MIL (U.S. Military Specifications)
  - ASTM (American Society for Testing Materials)
- Oil requirements
  - Diesel ...2 cycle versus 4 cycle
  - Gasoline
- Letter designations
  - S (spark ignition)
  - C (compression ignition)
- Growth of oil standards
  - CA ...moderate duty, 1940 & 50's high quality fuel ... obsolete
  - CB ...moderate duty, 1949, high sulfur fuel ... obsolete
  - CC ...moderate duty to severe duty, turbocharged, 1961 ...obsolete
  - CD ...severe duty, supercharged, 1955 ... active
  - CE ...severe duty, 1983, high speed and load operations ... active

VISCOSITY
- Ability of oil to stay fluid at a given temperature
- Varies as temperatures change
- Multigrade oil ... base oil 15W and polymers are added, expand as temperature increases
- "W" identifies lowest winter temperature requirement
- Viscosity recommendations
  - Select expected temperature range
  - 1st, 2nd or 3rd recommendation of oil usage
  - (Winter) applications

## LUGGER ENGINE OIL PERFORMANCE REQUIREMENTS

- Found in operator's manual (O.M.)
- John Deere engines designed to operate with oil temperature as high as 115˚ C (240˚ F)
- Higher output engines are equipped with oil coolers to maintain oil temperature below this limit
- Recommended API service classification:
  - CH - 4
  - CI - 4
  - CI - 4+
  - 15-40
  - MIL-L2104F is also current spec
  - See O.M. for Arctic oil viscosity grades
  - Multi weight preferred
- Base oil suppliers have to formulate oil to John Deere specs
- Additionally, use a special Lubrisol additive package to base oil to provide the extra protection required of today's high speed engines.
- Ash tolerance:
  - All the John Deere series of engines can tolerate ash levels up to 1 1/2%
  - Use oils with less than 1%
- Engines shipped "wet"
  - Break-in oil (10w30) - API rating: CC or CD
  - Factory fill oil has a dye that gives a yellowish color under black light.
  - High in zinc dithiophosphate anti-scuff additives.

Note: The use of an oil sampling program to help monitor engine performance and identify potential problems is recommended. OIL SCAN™ is John Deere's oil sampling program.

### OIL RATINGS

- SAE - Defines Viscosity
- API - Defines Quality
- MIL - Denotes Military Specifications
- ASTM - Mirrors API

Lube No. 3

### LUGGER NEEDS

| API | MIL |
|---|---|
| SB/CA | MIL-L-2104A |
| SC/CB | |
| SC/CC | MIL-L-2104B |
| SE/CD | |
| SF/CE | MIL-L-45199 |
| CH-4 | 15-40 Pref. |
| CI-4 | |

Lube No. 4

Depending on expected ambient air temperature between oil drain intervals, we recommend that engine lube oil conform to the oil viscosity as shown:

| | | |
|---|---|---|
| 0 - 122° F | -15 - 50° C | SAE 15W40 |
| -4 - 85° F | -20 - 30° C | SAE 10W30 |
| -22 - 65° F | -30 - 20° C | SAE 5W30 |
| -57 - 14° F | -10 - -55°C | Arctic Oil |

Lube No. 5

### LUBRICATING OIL

Lubricating oil for Lugger engines should conform to one of the following oil performance levels:

API SERVICE
Classifications
- CH - 4
- CI - 4
- CI - 4+

* Exceeds API Service Classification CE and passed John Deere (JDQ78) tests at high temperatures. Also meets engine oil performance requirements of CE/SG, C-3, to C-2, and MIL-L-2104D/E specifications.

Europe: CCMC specification D4 or D5

Lube No. 6

## ENGINE INSTALLATION ANGLES TO ENSURE ADEQUATE LUBRICATION

• Continuous - 15˚ (nose up), (static)

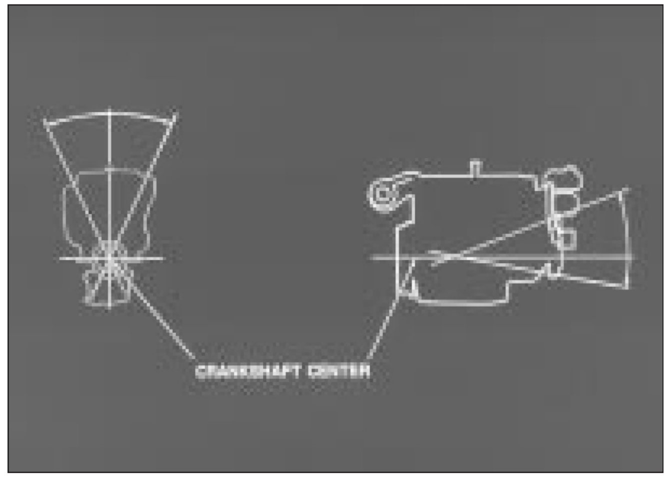
0˚ (nose down), (static)

• Operational Angularity:

- Continuous = 20˚

- Intermittent (max. any direction = 30˚

• Stable oil pressure must be maintained at all times




Lube No. 9

## PROCEDURE TO MARK DIPSTICK

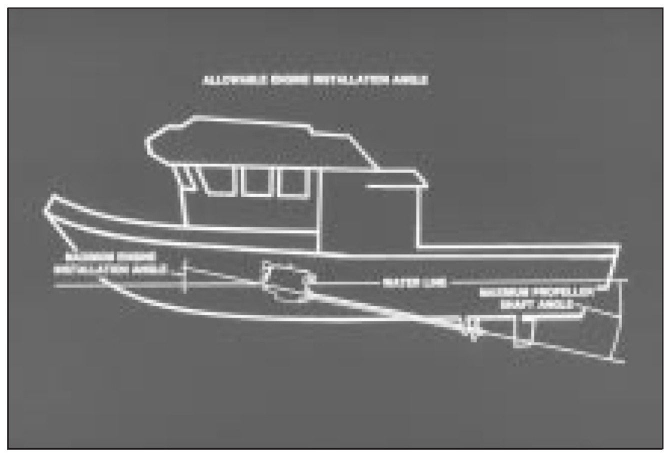
• If engine is installed at nose-up angle of 5˚ or more, engine dipstick must be re-marked

• Re-mark procedure:

- Fill and check oil level when engine is in a level position

- After 5˚ nose-up installation recheck dipstick mark and oil level.

- Remark dipstick to the new oil level.




Lube No. 10

## OPTIONAL DIPSTICK

• Elongated tube extends into sump

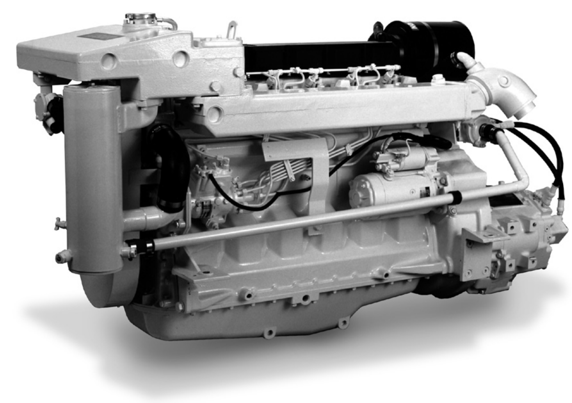
• Oil level can be checked while engine is running

Lube No. 11

# The Cooling System

Cooling system consists of:

- Engine water pump
- Thermostats
- Oil cooler
- Sea water pump
- Heat exchanger
- Keel cooler
- Expansion tank



Cool No. 1

COOLING SYSTEM PURPOSE

• Internal combustion engines produce heat during combustion of fuel.

• The cooling system controls the temperature of the engine within the range of highest operating efficiency.

• Adequate cooling is, therefore, essential to engine life.

**THE PURPOSE OF THE COOLING SYSTEM...**

to control the temperature of
the engine within the range of
highest operating efficiency

Cool No. 2

CLOSED SYSTEM AND OPEN SYSTEM COOLING

• Closed system can be either heat exchanger or keel cooler.

• Open system definitely not recommended.

Note: “Closed” cooling system also known as “fresh water” cooling; i.e., sea water (raw water) does not enter engine coolant galleries.

**MARINE ENGINE COOLING**

Closed System
A. Heat Exchanger
B. Keel Cooler

Open System
Not Recommended

Cool No. 3

## RAW WATER SYSTEM IMPORTANCE

- Cools engine coolant:
- Through heat exchanger
- Keel cooler
- Cools component skin temperature:
- Exhaust manifold
- Exhaust elbow
- Exhaust gases (if wet)
- Raw water (flotation water) - is the water outside hull, in which vessel floats

## PLUMBING, LOCATION, AND DRIVE OF SEA (RAW) WATER PUMPS

- Sea water must be plumbed to the engine driven sea water pump
- Engine auxiliary drive is used to drive sea water pump on Lugger engines

– Driven off engine coolant pump pulley (fan drive)

- Uses less than 2 hp to drive
- Includes belt guard
- Inlet circuit functions:
- Sea water lines must be large enough to provide flow to the pump within restriction guidelines.
- A seacock is needed to shut off the sea water flow during maintenance.
- Sea water strainers are required to keep foreign materials from reaching the pump.
- A sea water scoop is recommended to protect the inlet opening.

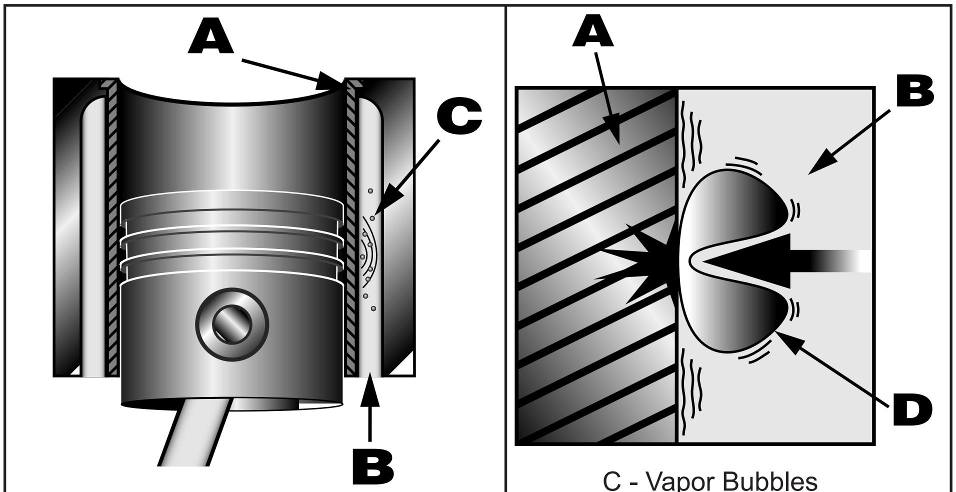
**COOLING MEDIUM**

Cooling Medium is flotation or external water provided through "Raw" Water System, sometimes referred to as "Sea" Water System.

Cool No. 4

Technical Bulletin: L423

# Prevention of cylinder liner erosion in wet sleeve diesel engines.



A - Cylinder Liner B - Engine Coolant

C - Vapor Bubbles
D - Collapsing Bubble

Note: This bulletin is based on recommendations Alaska Diesel Electric makes for our Lugger engines used in propulsion and generator applications. Consult your owners manual for detailed information on your model. Owners of other engine brands should consult their dealer for coolant system recommendations.

## WHAT CAUSES LINER EROSION (PITTING)

Most heavy-duty diesel engines have wet-sleeve type cylinder liners. These liners are replaceable inserts in the engine block that the piston rides up and down within. Being replaceable, they allow the engine to be overhauled without the engine block being removed from the vessel. The block can be rebuilt in place without ever going to a machine shop. The cylinder liner is surrounded by engine coolant to dissipate combustion heat.

The liners are made of extremely durable iron alloy. They resist large fluctuations in heat, friction and combustion detonation. Ironically, one of their biggest enemies is tiny vapor bubbles in the surrounding engine coolant.

When the piston reaches the top of its stroke, compressed fuel and air ignite. The impact causes the liner walls (A) to vibrate, sending pressure waves into the coolant (B). These waves cause vapor bubbles (C) to form.

These tiny vapor bubbles collect on the surface of metal parts. As the bubbles collapse (pop), a microscopic piece of metal is eroded from the metal part. Over a period of time, this pitting may progress completely through the cylinder liner. This allows coolant to enter the combustion chamber. Engine failure or other serious damage will result.

Unprotected engines with low quality water as coolant can have liner failure in as few as 500 hours.

## PROPER COOLANT RETARDS EROSION

To meet cooling system protection requirements, the coolant mixture must consist of:

a. Quality water

b. Ethylene glycol concentrate (EGC) commonly known as antifreeze.

c. Supplemental coolant additives (SCA's).

This mixture must be used year round to protect against freezing, boil-over, liner erosion or pitting and to provide a stable, noncorrosive environment for cooling system components.

Ethylene glycol concentrate (antifreeze) normally DOES NOT contain the SCA chemical inhibitors needed to control liner pitting.

Larger Lugger engines, (6108, 6125, 6140, 6170, 12V140) are equipped with a spin-on coolant filter-conditioner element which provides the SCA's to protect your cylinder liners.

The coolant filter-conditioner element performs two functions at once:

The outer paper element filters out rust, scale or dirt particles in the coolant.

The inner element releases SCA chemicals into the coolant to maintain a proper acid/alkaline balance, inhibit corrosion and suppress erosion pitting. The chemicals in the additives reduce the quantity of vapor bubbles. SCA also forms a protective film on the metal engine parts which act as a barrier against collapsing vapor bubbles.

## WATER QUALITY

Distilled, deionized, soft water is preferred for use in cooling systems. Bottled distilled water from a food store or water supplier is recommended. Tap water often has a high mineral content. Tap water should NEVER **be put in a cooling system unless first tested by an analytical laboratory that does water testing. See your Yellow Pages.**

**Here are acceptable water standards**

| Contaminates | Parts/ Million | Grains/ Gallon |
|---|---|---|
| Maximum Chlorides | 40 | 2.5 |
| Maximum Sulfates | 100 | 5.9 |
| Max Dissolved Solids | 340 | 20 |
| Max Total Hardness | 170 | 10 |
| PH level 5.5 to 9.0 | | |

If chlorides, sulfates or total dissolved solids are higher than the above given specification, the water must be distilled, demineralized, or deionized before it is used in a cooling system.

If total hardness is higher than 170 ppm and all other parameters are within the given specifications, the water must be softened before it is used to make coolant solution.

## ETHYLENE GLYCOL CONCENTRATE (ANTIFREEZE)

Ethylene glycol coolant concentrate (EGC) is commonly mixed with water to produce an engine coolant with a low freeze point and high boiling point.

Low silicate EGC is recommended for diesel engines. Use an EGC that meets ASTM D 4985p, SAEJ1941, D5345, D6210.

EGC is concentrated and should be mixed to the following specification.

| | H2O % | EGC % | Freeze Point | Boiling Point |
|---|---|---|---|---|
| Optimum | 50% | 50% | –37°C<br>–34° F | +109°C<br>+226° F |
| Minimum | 60% | 40% | –24°C<br>–12° F | +106°C<br>+222° F |
| Maximum | 40% | 60% | –52°C<br>–62° F | +111°C<br>+232° F |

If additional coolant solution needs to be added to the engine due to leaks or loss, the glycol concentration should be checked with a hydrometer to assure that the desired freeze point is maintained.

**Do not use methyl alcohol or methoxy propanol based EGC.** These concentrates are not compatible with chemicals used in supplemental coolant additives. Damage can occur to rubber seals on cylinder liners which are in contact with coolant.

**Do not use an EGC containing sealer or stop-leak additives.**

**Do not use EGC containing more than 0.1% anhydrous metasilicate.** This type of concentrate, which is intended for use in aluminum engines, may cause a gel-like deposit to form that reduces heat transfer and coolant flow.

! **CAUTION:** EGC (Antifreeze) is flammable, poisonous and harmful to the skin and eyes. Follow the instructions and warnings on the container carefully and keep out of reach of children and pets.

## SUPPLEMENTAL COOLANT ADDITIVE (SCA)

Supplemental coolant additive (SCA) is a vital part of your engines coolant mixture. It is critical in engines with wet sleeve type cylinder liners. SCAs can be added to the coolant in one of two ways:

1. added to the engine coolant mixture by the operator.
2. automatically added by the engine's spin-on coolant filter conditioner.

**Engines without coolant filter conditioners.**

If your engine does not have a coolant filter conditioner, you will have to add the Supplemental Coolant Additive to the engine's coolant mixture.

Always mix the solution of ethylene glycol concentrate (antifreeze) with quality water in a clean container before adding the SCA's. Then add the required amount of SCA to the mixture. Then add the resulting mixture to the engine cooling system.

Never pour cold coolant into a hot engine, as it may crack engine block or cylinder head.

Do not add more SCA than recommended. Coolant solutions with higher than recommended SCA concentrations can cause silicate-dropout. When this happens, a gel-type deposit is created which retards heat transfer and coolant flow.

For Lugger engines: liquid SCA must be added at a rate of 3%, by volume, to the coolant mixture. (30 mL of SCA per Liter of $H_2O$/EGC mixture. 1.0 fluid oz of SCA per quart of $H_2O$/EGC)

SCA is available from your Northern Lights/Lugger dealer in two sizes.

Pint - Part No 20-00002

1/2 gallon - Part No 20-00003

**Engines <u>with</u> coolant filter conditioners**

If your engine has a coolant-conditioner, additional SCA's should NOT be manually added to the mixture of EGC and water when initially filling the engine's cooling system. A high SCA concentration will result and can cause silicate-dropout problems.

The only exception to this rule is on marine engines with keel coolers or industrial engines with heat recovery or other special cooling systems. These special systems have large coolant capacities. The SCA in the spin on filter may not be able to treat the large volume of coolant. The operator must use a test kit strip to determine the amount of additional SCA's that needs to be added to the cooling system.

If additional SCA's are needed, prepare a mixture as described above (50%H2O/50%EGC +3%SCA).

Add the resulting mixture to the cooling system in one quart (liter) increments. Run the engine for 1 hour and retest the coolant. Repeat the process until the test strips show the SCA concentration meets recommended levels.

If your engine has a coolant conditioner, ALWAYS change the element according to your owner's manual and note the change in your engine maintenance log.

**All Engines:**

**DO NOT use any coolant system additives containing soluble oil.**

**! CAUTION: Supplemental coolant additive contains alkali and is poisonous and harmful to the skin and eyes. Follow the instructions and warnings on the container carefully and keep out of reach of children and pets.**

## PREMIXED COOLING FLUID

Premixed cooling fluids are marketed for use in the engine cooling system. Cooling fluid contains the proper mixture of quality water, low silicate antifreeze and supplemental coolant additives. This cooling fluid protects the engine against freezing down to –35°F (–37°C) .

**Important:** Additional SCA's should NOT be added to premixed engine cooling fluid on initial fill up. It may be necessary to add SCA later if testing indicates the SCA level in the cooling fluid is depleted.

**Important:** Do **not** use premixed engine cooling fluid and a spin-on coolant element together.

Premixed cooling fluid is available from your Northern Lights or Lugger Dealer in one gallon containers (Part Number 20-00001)

## COOLANT TESTING

Coolant test kits are available to allow on-site evaluation of the coolant condition. The kits use small strips of paper which are dipped into the coolant. The paper changes color and indicates the SCA concentration. It also indicates the amount of EGC (antifreeze).

Test kits are available through your Northern Lights or Lugger Dealer.

4 Pack - Part No.................20-00005

50 Pack - Part No..............20-00010

**! CAUTION: The cooling water in the engine reaches extremely high temperatures. You must use extreme caution when working on hot engines to avoid burns. Allow the engine to cool before working on the cooling system. Open the filler cap carefully, using protective clothing.**

Other Technical Bulletins are available from Alaska Diesel Electric. Visit you Lugger/Northern Lights dealer for more information and application advice.

## ALIGNMENT

• When aligning the engine, check both the marine gear output flange bore and face alignment with the mating propeller shaft flange.

• The bore alignment must be exact (zero misalignment) to allow the two flanges to mate together.

- The flanges should never be forced to fit.

- The face alignment must be within 0.13 mm (0.005 in.) when checked with a feeler gauge at the top, bottom, and both sides.

• Final alignment should not be done until the vessel is in the water and loaded to its normal draft. A solid mounting system should fall within the alignment limits when rechecked. Because a flexible system moves when the engine is run, it cannot be rechecked. Each time flexible shafting is disconnected, the engine must be realigned.

## VIBRATION

• Two types of vibrations generated to engine and driveline.

- Linear vibration

- Torsional vibration

• Linear vibration is caused when the engine is out of alignment, or by an out-of-balance condition in the shafting or propeller.

-Weak hull structure can also cause vibration because the engine is not held in alignment.

- Reinforcing the engine stringers or adding cross ties will help stiffen the supporting structure.

• A torsional analysis is a mathematical study of the rotating masses and inertias of the engine, marine gear and drive system.

- Marine classification societies, ABS, Lloyd's, Bureau Veritas, require a torsional analysis of a propulsion or gen-set system as part of their approval process. The acceptable limits are set by each society.

- Marine gear manufacturers may also request a torsional analysis.

• Most common torsional vibration complaint in a marine propulsion system is marine gear clatter at low speeds.

- Problem is usually caused by resetting the engine idle speed below normal factory recommended idle rpm.

- May be eliminated by raising the idle speed to the normal rpm and using a trolling valve in the marine gear to reduce propeller rpm at idle.

• Other recommendations in application manual.

## VIBRATION

| TORSIONAL | LINEAR |
|---|---|
| Speed Specific | All Speeds |
| Variation in Engine Torques | Unbalance or Alignment |
| Vibration is not felt | Shakes the Boat |
| | |
| Failures include: | Failures include: |
| Damper | Brackets |
| Crankshaft | Vibration Isolators |
| Engine Gear Train | Engine Mounted Instruments |
| Torsional Couplings | Noise |
| Marine Gears | Hull Vibration |
| Gear Clatter at Idle | |

## HEAD BOLT TORQUE-TO-YIELD TIGHTENING PROCEDURE

• Lubricate bolts with clean SAE30 engine oil (DO NOT use multi-viscosity oils as lubricity may dissipate during tightening sequence, and install in their proper locations

• Tighten bolt No. 17 to 80 N•m (60 lb-ft). Sequentially (Tighten all bolts to 80 N•m [60 lb-ft] starting at bolt No. 1 through bolt No. 26)

• Using an oil proof marker, scribe a line parallel to the crankshaft across the entire top of each bolt head. This line will be used as a reference mark

• IMPORTANT: If a bolt is accidentally tightened more than 90˚ in any one sequence, DO NOT loosen bolt but make adjustments in the next tightening sequence

• Sequentially (start at bolt No. 1 and proceed through bolt No. 26) turn each bolt approximately 90˚. Line on top of bolt will be about perpendicular to crankshaft

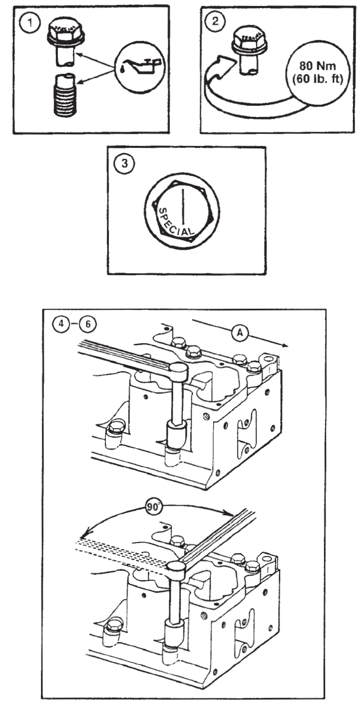
• Again, sequentially (start at bolt No. 1 and proceed through bolt No. 26) turn each bolt approximately 90˚. Line on top of bolt will again be about parallel to crankshaft

• IMPORTANT: Head bolts MUST NOT be tightened more than a total of 270˚±5˚

• Finally, sequentially (start at bolt No. 1 and proceed through bolt No. 26) turn each bolt approximately 90˚, SO THAT LINE ON TOP OF BOLT IS AS CLOSE AS POSSIBLE TO BEING PERPENDICULAR TO THE CRANKSHAFT. It is not necessary to obtain the final turn in one swing of the wrench. TOTAL AMOUNT OF TURN FROM STEPS 4, 5, AND 6 IS 270˚ ± 5˚

• Average clamp loads per bolt, with this procedure is 25,000 lbs vs. 23,500 lb (torque-turn)

**TORQUE-TO-YIELD**



# Application Formulas

| Desired Data | Single Phase | Three Phase |
|---|---|---|
| Kilo Volt - Amperes (KVA) | $\frac{\text{Volts x AMPS}}{1000}$ $\frac{\text{KW}}{\text{P.F.}}$ | $\frac{\text{1.73 x volts x AMPS}}{1000}$ $\frac{\text{KW}}{\text{P.F.}}$ |
| Kilowatts (KW) | $\frac{\text{Volts x AMPS x P.F.}}{1000}$ or KVA x P.F. | $\frac{\text{1.73 x Volts x AMPS x P.F.}}{1000}$ or KVA x P.F. |
| Power Factor (P.F.) | $\frac{\text{KW}}{\text{KVA}}$ | $\frac{\text{KW}}{\text{KVA}}$ |
| Amperes - When KW is known | $\frac{\text{KW x 1000}}{\text{Volts x P.F.}}$ | $\frac{\text{KW x 1000}}{\text{1.73 x Volts x P.F.}}$ |
| Amperes - When KVA is known | $\frac{\text{KVA x 1000}}{\text{Volts}}$ | $\frac{\text{KVA x 1000}}{\text{1.73 x Volts}}$ |
| Required Prime Mover H.P. | $\frac{\text{KW}}{\text{Alternator Efficiency x .746}}$ | |
| Frequency (Hertz) | $\frac{\text{Number of Poles x RPM}}{120}$ | |
| Revolutions Per Minute (RPM) | $\frac{\text{Hertz x 120}}{\text{Number of Poles}}$ | |
| Voltage Regulation (in %) | $\frac{\text{No Load Voltage - Full Load Voltage x 100}}{\text{Full Load Voltage}}$ | |
| Speed Regulation (in %) | $\frac{\text{No Load RPM - Full Load RPM x 100}}{\text{Full Load RPM}}$ | |
| Voltage Dip Factor (motor starting) | $\left(\frac{\text{100\% - Voltage Dip \%}}{100}\right)^2$ | |

# Alternator Full Load Ratings

FULL LOAD AMPERAGE RATING - UNITY (100%) POWER FACTOR
SINGLE PHASE GENERATORS

| KVA | 115V | 120V | 240V |
|---|---|---|---|
| 2.5 | 22.0 | 21.0 | 11.0 |
| 3.0 | 26.0 | 25.0 | 13.0 |
| 3.5 | 30.0 | 29.0 | 15.0 |
| 5.0 | 43.0 | 42.0 | 22.0 |
| 6.25 | 54.0 | 52.0 | 27.0 |
| 7.5 | 65.0 | 63.0 | 33.0 |
| 10.0 | 87.0 | 83.0 | 43.0 |
| 12.5 | 109.0 | 104.0 | 54.0 |
| 15.0 | 130.0 | 125.0 | 65.0 |
| 18.75 | 163.0 | 156.0 | 82.0 |
| 25.0 | 217.0 | 208.0 | 109.0 |
| 31.25 | 272.0 | 260.0 | 136.0 |
| 37.5 | 326.0 | 313.0 | 163.0 |
| 43.75 | 380.0 | 365.0 | 190.0 |
| 50.0 | 435.0 | 417.0 | 217.0 |
| 62.5 | 543.0 | 521.0 | 272.0 |
| 75.0 | 652.0 | 625.0 | 326.0 |
| 93.8 | 816.0 | 782.0 | 408.0 |
| 125.0 | 1087.0 | 1041.0 | 543.0 |

FULL LOAD AMPERAGE RATINGS - 80% POWER FACTOR
THREE PHASE GENERATORS

| KVA | KW | 208V | 220V | 230V | 240V | 380V | 416V | 440V | 460V | 480V | 600V |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.3 | 5 | 18 | 17 | 16 | 15 | 10 | 9 | 8 | 8 | 8 | 6 |
| 9.4 | 7 | 26 | 25 | 24 | 23 | 14 | 13 | 12 | 12 | 11 | 9 |
| 12.5 | 10 | 35 | 33 | 31 | 30 | 19 | 17 | 16 | 16 | 15 | - |
| 18.7 | 15 | 52 | 49 | 47 | 45 | 28 | 26 | 25 | 24 | 23 | 18 |
| 25.0 | 20 | 69 | 66 | 63 | 60 | 38 | 35 | 33 | 31 | 30 | 24 |
| 31.3 | 25 | 87 | 82 | 79 | 79 | 48 | 43 | 41 | 39 | 38 | 30 |
| 37.5 | 30 | 104 | 99 | 94 | 90 | 57 | 52 | 49 | 47 | 45 | 36 |
| 50.0 | 40 | 139 | 131 | 126 | 120 | 76 | 69 | 66 | 63 | 60 | 48 |
| 62.5 | 50 | 174 | 164 | 157 | 150 | 95 | 87 | 82 | 78 | 75 | 61 |
| 75.0 | 60 | 208 | 197 | 188 | 180 | 114 | 104 | 99 | 94 | 90 | 72 |
| 93.8 | 75 | 260 | 246 | 235 | 226 | 143 | 130 | 123 | 118 | 113 | 90 |
| 125.0 | 100 | 374 | 328 | 314 | 301 | 190 | 174 | 164 | 157 | 150 | 120 |
| 156.0 | 125 | 433 | 410 | 392 | 375 | 237 | 217 | 205 | 196 | 188 | 150 |
| 187.0 | 150 | 519 | 491 | 469 | 450 | 285 | 260 | 246 | 235 | 225 | 180 |
| 219.0 | 175 | 608 | 575 | 550 | 527 | 333 | 304 | 288 | 275 | 263 | 211 |
| 250.0 | 200 | 694 | 657 | 628 | 601 | 380 | 347 | 328 | 314 | 301 | 241 |
| 312.0 | 250 | 866 | 819 | 783 | 751 | 475 | 433 | 410 | 392 | 375 | 300 |
| 375.0 | 300 | 1040 | 985 | 941 | 902 | 570 | 521 | 493 | 471 | 451 | 361 |
| 438.0 | 350 | 1217 | 1151 | 1101 | 1055 | 666 | 609 | 575 | 550 | 528 | 430 |
| 500.0 | 400 | 1390 | 1314 | 1257 | 1204 | 761 | 695 | 657 | 628 | 602 | 482 |
| 656.0 | 525 | 1820 | 1720 | 1646 | 1578 | 997 | 910 | 860 | 823 | 789 | 631 |
| 750.0 | 600 | 2082 | 1968 | 1883 | 1804 | 1139 | 1041 | 984 | 941 | 902 | 722 |
| 900.0 | 725 | 2428 | 2296 | 2197 | 2105 | 1329 | 1214 | 1148 | 1098 | 1052 | 842 |
| 1030.0 | 825 | 2776 | 2624 | 2510 | 2406 | 1519 | 1388 | 1312 | 1255 | 1203 | 962 |
| 1155.0 | 925 | 3122 | 2952 | 2824 | 2706 | 1709 | 1561 | 1476 | 1412 | 1353 | 1083 |
| 1340.0 | 1075 | 3470 | 3280 | 3138 | 3007 | 1899 | 1735 | 1640 | 1569 | 1504 | 1203 |

# Motor Full Load Current Data

## LOCKED-ROTOR INDICATING CODE LETTERS

| Code Letter | Kilovolt-Amperes per Horsepower with Locked Rotor | Code Letter | Kilovolt-Amperes Per Horsepower with Locked Rotor |
|---|---|---|---|
| A | 0-3.14 | L | 9.0-9.99 |
| B | 3.15-3.54 | M | 10.0-11.19 |
| C | 3.55-3.99 | N | 11.2-12.49 |
| D | 4.0-4.49 | P | 12.5-13.99 |
| E | 4.5-4.99 | R | 14.0-15.99 |
| F | 5.0-5.59 | S | 16.0-17.00 |
| G | 5.6-6.29 | T | 18.0-19.99 |
| H | 6.3-7.09 | U | 29.0-22.39 |
| J | 7.1-7.99 | V | 22.4 and up |
| K | 8.0-8.99 | | |

## FULL LOAD CURRENTS IN AMPERES, SINGLE-PHASE ALTERNATING-CURRENT MOTORS

The following values of full-load currents are for motors running at usual speeds and motors with normal torque characteristecs. Motors built for especially low speeds or high torques may have higher full-load currents, and multispeed motors will have full-load current varying with speed, in which case the namplate current ratings shall be used.

The voltage listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120 and 220 to 240 volts.

| Horsepower | 115 Volts | 200 Volts | 208 Volts | 230 Volts |
|---|---|---|---|---|
| 1/6 | 4.4 | 2.5 | 2.4 | 2.2 |
| 1/4 | 5.8 | 3.3 | 3.2 | 2.9 |
| 1/3 | 7.2 | 4.1 | 4.0 | 3.6 |
| 1/2 | 9.8 | 5.6 | 5.4 | 4.9 |
| 3/4 | 13.8 | 7.9 | 7.6 | 6.9 |
| 1 | 16 | 9.2 | 8.8 | 8.0 |
| 1-1/2 | 20 | 11.5 | 11.0 | 10 |
| 2 | 24 | 13.8 | 13.2 | 12 |
| 3 | 34 | 19.6 | 18.7 | 17 |
| 5 | 56 | 32.2 | 30.8 | 28 |
| 7-1/2 | 80 | 46.0 | 44.0 | 40 |
| 10 | 100 | 57.5 | 55.0 | 50 |

## FULL LOAD CURRENTS THREE-PHASE ALTERNATING-CURRENT MOTORS

The following values of full-load currents are typical for motors running at speeds usual for belted motors and motors with normal torque characteristics.

Motors built for low speeds (1200 rpm or less) or high torques may require more running current, and multispeed motors will have full-load current varying with speed. In these cases, the nameplate current rating shall be used.

The voltage listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 - 120, 220 - 240, 440 - 480, & 550 - 600 volts.

| | Induction Type Squirrel Cage and Wound Rotor (Amperes) | | | | | | | Synchronous-Type Unity Power Factor* (Amperes) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Horsepower | 115 Volts | 200 Volts | 208 Volts | 230 Volts | 460 Volts | 575 Volts | 2300 Volts | 230 Volts | 460 Volts | 575 Volts | 2300 Volts |
| 1/2 | 4.4 | 2.5 | 2.4 | 2.2 | 1.1 | 0.9 | - | - | - | - | - |
| 3/4 | 6.4 | 3.7 | 3.5 | 3.2 | 1.6 | 1.3 | - | - | - | - | - |
| 1 | 8.4 | 4.8 | 4.6 | 4.2 | 2.1 | 1.7 | - | - | - | - | - |
| 1 1/2 | 12.0 | 6.9 | 6.6 | 6.0 | 3.0 | 2.4 | - | - | - | - | - |
| 2 | 13.6 | 7.8 | 7.5 | 6.8 | 3.4 | 2.7 | - | - | - | - | - |
| 3 | - | 11.0 | 10.6 | 9.6 | 4.8 | 3.9 | - | - | - | - | - |
| 5 | - | 17.5 | 16.7 | 15.2 | 7.6 | 6.1 | - | - | - | - | - |
| 7 1/2 | - | 25.3 | 24.2 | 22 | 11 | 9 | - | - | - | - | - |
| 10 | - | 32.2 | 30.8 | 28 | 14 | 11 | - | - | - | - | - |
| 15 | - | 48.3 | 46.2 | 42 | 21 | 17 | - | - | - | - | - |
| 20 | - | 62.1 | 59.4 | 54 | 27 | 22 | - | - | - | - | - |
| 25 | - | 78.2 | 74.8 | 68 | 34 | 27 | - | 53 | 26 | 21 | - |
| 30 | - | 92 | 88 | 80 | 40 | 32 | - | 63 | 32 | 26 | - |
| 40 | - | 120 | 114 | 104 | 52 | 41 | - | 83 | 41 | 33 | - |
| 50 | - | 150 | 143 | 130 | 65 | 52 | - | 104 | 52 | 42 | - |
| 60 | - | 177 | 169 | 154 | 77 | 62 | 16 | 123 | 61 | 49 | 12 |
| 75 | - | 221 | 211 | 192 | 96 | 77 | 20 | 155 | 78 | 62 | 15 |
| 100 | - | 285 | 273 | 248 | 124 | 99 | 26 | 202 | 101 | 81 | 20 |
| 125 | - | 359 | 343 | 312 | 156 | 125 | 31 | 253 | 126 | 101 | 25 |
| 150 | - | 414 | 396 | 360 | 180 | 144 | 37 | 302 | 151 | 121 | 30 |
| 200 | - | 552 | 528 | 480 | 240 | 192 | 49 | 400 | 201 | 161 | 40 |
| 250 | - | - | - | - | 302 | 242 | 60 | - | - | - | - |
| 300 | - | - | - | - | 361 | 289 | 72 | - | - | - | - |
| 350 | - | - | - | - | 414 | 336 | 83 | - | - | - | - |
| 400 | - | - | - | - | 477 | 382 | 95 | - | - | - | - |
| 450 | - | - | - | - | 515 | 412 | 103 | - | - | - | - |
| 500 | - | - | - | - | 590 | 472 | 118 | - | - | - | - |

*For 90 and 80 percent power factor, the figures shall be multiplied by 1.1 and 1.25, respectively.

# Ampacities of multiconductor cable

Ampacities of Multiconductor Cables with Not More than Three Insulated Conductors, Rated 0 Through 2000 Volts, in Free Air Based on Ambient Temperature of 40KC (104˚) (For Types TC, MC, MI, UF, and USE Cables)

| Size | | | | | | | | | Size |
|---|---|---|---|---|---|---|---|---|---|
| | 60˚C (140˚F) | 75˚C (167˚F) | 85˚C (185˚F) | 90˚C (194˚F) | 60˚C (140˚F) | 75˚C (167˚F) | 85˚C (185˚F) | 90˚C (194˚F) | |
| AWG or kcmil | COPPER | | | | ALUMINUM OR COPPER-CLAD ALUMINUM | | | | AWG or kcmil |
| 18 | - | - | - | 11* | - | - | - | - | 18 |
| 16 | - | - | - | 16* | - | - | - | - | 16 |
| 14 | 18* | 21* | 24* | 25* | - | - | - | - | 14 |
| 12 | 21* | 28* | 30* | 32* | 18* | 21* | 24* | 25* | 12 |
| 10 | 28* | 36* | 41* | 43* | 21* | 288 | 30* | 32* | 10 |
| 8 | 39 | 50 | 56 | 59 | 30 | 39 | 44 | 46 | 8 |
| 6 | 52 | 68 | 75 | 79 | 41 | 53 | 59 | 61 | 6 |
| 4 | 69 | 89 | 100 | 104 | 54 | 70 | 78 | 81 | 4 |
| 3 | 81 | 104 | 116 | 121 | 63 | 81 | 91 | 95 | 3 |
| 2 | 92 | 118 | 132 | 138 | 72 | 92 | 103 | 108 | 2 |
| 1 | 107 | 138 | 154 | 161 | 84 | 108 | 120 | 126 | 1 |
| 1/0 | 124 | 160 | 178 | 186 | 97 | 125 | 139 | 145 | 1/0 |
| 2/0 | 143 | 184 | 206 | 215 | 111 | 144 | 160 | 168 | 2/0 |
| 3/0 | 165 | 213 | 238 | 24/ | 129 | 166 | 185 | 194 | 3/0 |
| 4/0 | 190 | 245 | 274 | 287 | 149 | 192 | 214 | 224 | 4/0 |
| 250 | 212 | 274 | 305 | 320 | 166 | 214 | 239 | 250 | 250 |
| 300 | 237 | 306 | 341 | 357 | 186 | 240 | 268 | 280 | 300 |
| 350 | 261 | 337 | 377 | 394 | 205 | 265 | 296 | 309 | 350 |
| 400 | 281 | 363 | 406 | 425 | 222 | 287 | 317 | 334 | 400 |
| 500 | 321 | 416 | 465 | 487 | 255 | 330 | 368 | 385 | 500 |
| 600 | 354 | 459 | 513 | 538 | 284 | 368 | 410 | 429 | 600 |
| 700 | 387 | 502 | 562 | 589 | 306 | 405 | 462 | 473 | 700 |
| 750 | 404 | 523 | 586 | 615 | 328 | 424 | 473 | 495 | 750 |
| 800 | 415 | 539 | 604 | 633 | 339 | 439 | 490 | 513 | 800 |
| 900 | 438 | 570 | 639 | 670 | 362 | 469 | 514 | 548 | 900 |
| 1000 | 461 | 601 | 674 | 707 | 385 | 499 | 558 | 584 | 1000 |
| Ambient Temp. (˚C) | For ambient temperatures other than 40˚C (104˚), multiply the ampacities shown above by the appropriate factor shown below. | | | | | | | | Ambient Temp. (˚F) |
| 21-25 | 1.32 | 1.20 | 1.15 | 1.14 | 1.32 | 1.20 | 1.15 | 1.14 | 70-77 |
| 26-30 | 1.22 | 1.13 | 1.11 | 1.10 | 1.22 | 1.13 | 1.11 | 1.10 | 79-86 |
| 31-35 | 1.12 | 1.07 | 1.05 | 1.05 | 1.12 | 1.07 | 1.05 | 1.05 | 88-95 |
| 36-40 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 97-104 |
| 41-45 | 0.87 | 0.93 | 0.94 | 0.95 | 0.87 | 0.93 | 0.94 | 0.95 | 106-113 |
| 46-50 | 0.71 | 0.85 | 0.88 | 0.89 | 0.71 | 0.85 | 0.88 | 0.89 | 115-122 |
| 51-55 | 0.50 | 0.76 | 0.82 | 0.84 | 0.50 | 0.76 | 0.82 | 0.84 | 124-131 |
| 56-60 | - | 0.65 | 0.75 | 0.77 | - | 0.65 | 0.75 | 0.77 | 133-140 |
| 61-70 | - | 0.38 | 0.58 | 0.63 | - | 0.38 | 0.58 | 0.63 | 142-158 |
| 71-80 | - | - | 0.33 | 0.44 | - | - | 0.33 | 0.44 | 160-176 |

*Unless otherwise specifically permitted elsewhere in the Code, the overcurrent protection for these conductor types shall not exceed 15 amperes for No. 14, 20 amperes for No. 12, and 30 amperes for No. 10 copper; or 15 amperes for No. 12 and 25 amperes for no. 10 aluminum and copper-clad aluminium.

Ampacities of Two or Three Insulated Conductor, Rated 0 through 2000 Volts, Within an Overall Covering (Multiconductor Cable), in Raceway in Free Air Based on Amvient Air Temperature of 30˚C (86˚F)

| Size | | | | | | | Size |
|---|---|---|---|---|---|---|---|
| | 60˚C (140˚F) | 75˚C (167˚F) | 90˚C (194˚F) | 60˚C (140˚F) | 75˚C (167˚F) | 90˚C (194˚F) | |
| AWG or kcmil | Types TW, UF | Types RH, RHW THHW, THW, THWN, XHHW, ZW | Types THHN, THHW, THW-2, THWN-2, RHH, RWH-2, USE-2, XHHW, XHHW-2, ZW-2 | Type TW | Types RH, RHW, THHW, THW, THWN XHHW | Types THHN, THHW, THW-2, THWN-2, RHH, RWH-2, USE-2, XHHW, XHHW-2, ZW-2 | AWG or kcmil |
| | COPPER | | | ALUMINUM OR COPPER-CLAD ALUMINUM | | | |
| 14 | 16* | 18* | 21* | - | - | - | 14 |
| 12 | 20* | 24* | 27* | 16* | 18* | 21* | 12 |
| 10 | 27* | 33* | 36* | 21* | 25* | 28* | 10 |
| 8 | 36 | 43 | 48 | 28 | 33 | 37 | 8 |
| 6 | 48 | 58 | 65 | 38 | 45 | 51 | 6 |
| 4 | 66 | 79 | 89 | 51 | 61 | 69 | 4 |
| 3 | 76 | 90 | 102 | 59 | 70 | 79 | 3 |
| 2 | 88 | 105 | 119 | 69 | 83 | 93 | 2 |
| 1 | 102 | 121 | 137 | 80 | 95 | 106 | 1 |
| 1/0 | 121 | 145 | 163 | 94 | 113 | 127 | 1/0 |
| 2/0 | 138 | 166 | 186 | 108 | 129 | 146 | 2/0 |
| 3/0 | 158 | 189 | 214 | 124 | 147 | 167 | 3/0 |
| 4/0 | 187 | 223 | 253 | 147 | 176 | 197 | 4/0 |
| 250 | 205 | 245 | 276 | 160 | 192 | 217 | 250 |
| 300 | 234 | 281 | 317 | 185 | 221 | 250 | 300 |
| 350 | 255 | 305 | 345 | 202 | 242 | 273 | 350 |
| 400 | 274 | 328 | 371 | 218 | 261 | 295 | 400 |
| 500 | 315 | 378 | 427 | 254 | 303 | 342 | 500 |
| 600 | 343 | 413 | 468 | 279 | 335 | 378 | 600 |
| 700 | 376 | 452 | 514 | 310 | 371 | 420 | 700 |
| 750 | 387 | 466 | 529 | 321 | 384 | 435 | 750 |
| 800 | 397 | 479 | 543 | 331 | 397 | 450 | 800 |
| 900 | 415 | 500 | 570 | 350 | 421 | 477 | 900 |
| 1000 | 448 | 542 | 617 | 382 | 460 | 521 | 1000 |
| Ambient Temp. (˚C) | For ambient temperatures other than 30˚C (86˚), multiply the ampacities shown above by the appropriate factor shown below. | | | | | | Ambient Temp. (˚F) |
| 21-25 | 1.08 | 1.05 | 1.04 | 1.08 | 1.05 | 1.04 | 70-77 |
| 26-30 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 79-86 |
| 31-35 | 0.91 | 0.94 | 0.96 | 0.91 | 0.94 | 0.96 | 88-95 |
| 36-40 | 0.82 | 0.88 | 0.91 | 0.82 | 0.88 | 0.91 | 97-104 |
| 41-45 | 0.71 | 0.82 | 0.87 | 0.71 | 0.82 | 0.87 | 106-113 |
| 46-50 | 0.58 | 0.75 | 0.82 | 0.58 | 0.75 | 0.82 | 115-122 |
| 51-55 | 0.41 | 0.67 | 0.76 | 0.41 | 0.67 | 0.76 | 124-131 |
| 56-60 | - | 0.58 | 0.71 | - | 0.58 | 0.71 | 133-140 |
| 61-70 | - | 0.33 | 0.58 | - | 0.33 | 0.58 | 142-158 |
| 71-80 | - | - | 0.41 | - | - | 0.41 | 160-176 |

*Unless otherwise specifically permitted elsewhere in the Code, the overcurrent protection for these conductor types shall not exceed 15 amperes for No. 14, 20 amperes for No. 12, and 30 amperes for No. 10 copper; or 15 amperes for No. 12 and 25 amperes for no. 10 aluminum and copper-clad aluminium.

# Allowable Ampacities of Insulated Conductors Rated 0-2000 Volts, 60˚ to 90˚C

Single conductors in free air, based on ambient temperature of 30˚C (86˚F)

| Size | Temperature rating of conductor | | | | | | | | Size |
|---|---|---|---|---|---|---|---|---|---|
| | 60˚C (140˚F) | 75˚C (167˚F) | 85˚C (185˚F) | 90˚C (194˚F) | 60˚C (140˚F) | 75˚C (167˚F) | 85˚C (185˚F) | 90˚C (194˚F) | |
| | TYPES | TYPES | TYPES | TYPES | TYPES | TYPES | TYPES | TYPES | |
| AWG MCM | RUW, T, TW | FEPW, RH, RHW, RUH, THW, THWN, XHHW, ZW | V, MI | TA, TBS, SA, AVB, SIS, FEP, FEPB, RHH, THHN, XHHW | RUW, T, TW | RH, RHW, RUH, THW, THWN, XHHW | V, MI | TA, TBS, SA, AVB, SIS, RHH, THHN, XHHW | AWG MCM |
| | COPPER | | | | ALUMINUM OR COPPER-CLAD ALUMINUM | | | | |
| 18 | - | - | - | 18 | - | - | - | - | - |
| 16 | - | - | 23 | 24 | - | - | - | - | - |
| 14 | 25 | 30 | 30 | 35 | - | - | - | - | - |
| 12 | 30 | 35 | 40 | 40 | 25 | 30 | 30 | 35 | 12 |
| 10 | 40 | 50 | 55 | 55 | 35 | 40 | 40 | 40 | 10 |
| 8 | 60 | 70 | 75 | 80 | 45 | 55 | 60 | 60 | 8 |
| 6 | 80 | 95 | 100 | 105 | 60 | 75 | 80 | 80 | 6 |
| 4 | 105 | 125 | 135 | 140 | 80 | 100 | 105 | 110 | 4 |
| 3 | 120 | 145 | 160 | 165 | 95 | 115 | 125 | 130 | 3 |
| 2 | 140 | 170 | 185 | 190 | 110 | 135 | 145 | 150 | 2 |
| 1 | 165 | 195 | 215 | 220 | 130 | 155 | 165 | 175 | 1 |
| 0 | 195 | 230 | 250 | 260 | 150 | 180 | 195 | 205 | 0 |
| 00 | 225 | 265 | 290 | 300 | 175 | 210 | 225 | 235 | 00 |
| 000 | 260 | 310 | 335 | 350 | 200 | 240 | 265 | 275 | 000 |
| 0000 | 300 | 360 | 390 | 405 | 235 | 280 | 305 | 315 | 0000 |
| 250 | 340 | 405 | 440 | 455 | 265 | 315 | 345 | 355 | 250 |
| 300 | 375 | 445 | 485 | 505 | 290 | 350 | 380 | 395 | 300 |
| 350 | 420 | 505 | 550 | 570 | 330 | 395 | 430 | 445 | 350 |
| 400 | 455 | 545 | 595 | 615 | 355 | 425 | 465 | 480 | 400 |
| 500 | 515 | 620 | 675 | 700 | 405 | 485 | 525 | 545 | 500 |
| 600 | 575 | 690 | 750 | 780 | 455 | 540 | 595 | 615 | 600 |
| 700 | 630 | 755 | 825 | 855 | 500 | 595 | 650 | 675 | 700 |
| 750 | 655 | 785 | 855 | 885 | 515 | 620 | 675 | 700 | 750 |
| 800 | 680 | 815 | 885 | 920 | 535 | 645 | 700 | 725 | 800 |
| 900 | 730 | 870 | 950 | 985 | 580 | 700 | 760 | 785 | 900 |
| 1000 | 780 | 935 | 1020 | 1055 | 625 | 750 | 815 | 845 | 1000 |
| 1250 | 890 | 1065 | 1160 | 1200 | 710 | 855 | 930 | 960 | 1250 |
| 1500 | 980 | 1175 | 1275 | 1325 | 795 | 950 | 1035 | 1075 | 1500 |
| 1750 | 1070 | 1280 | 1395 | 1445 | 875 | 1050 | 1145 | 1185 | 1750 |
| 2000 | 1155 | 1385 | 1505 | 1560 | 960 | 1150 | 1250 | 1335 | 2000 |

# Allowable Ampacities of Insulated Conductors Rated 0-2000 Volts, 60˚ to 90˚C

Not more than three conductors in raceway or cable or earth (directly buried), based on ambient temperature of 30˚C (86˚F)

| Size | Temperature rating of conductor | | | | | | | | Size |
|---|---|---|---|---|---|---|---|---|---|
| | 60˚C (140˚F) | 75˚C (167˚F) | 85˚C (185˚F) | 90˚C (194˚F) | 60˚C (140˚F) | 75˚C (167˚F) | 85˚C (185˚F) | 90˚C (194˚F) | |
| AWG MCM | TYPES RUW, T, TW, UF | TYPES FEPW, RH, RHW, RUH, THW, THWN, XHHW, USE, ZW | TYPES V, MI | TYPES TA, TBS, SA, AVB, SIS, FEP, FEPB, RHH, THHN, XHHW | TYPES RUW, T, TW, UF | TYPES RH, RHW, RUH, THW, THWN, XHHW, USE | TYPES V, MI | TYPES TA, TBS, SA, AVB, SIS, RHH, THHN, XHHW | AWG MCM |
| | COPPER | | | | ALUMINUM OR COPPER-CLAD ALUMINUM | | | | |
| 18 | - | - | - | 14 | - | - | - | - | - |
| 16 | - | - | 18 | 18 | - | - | - | - | - |
| 14 | 20 | 20 | 25 | 25 | - | - | - | - | - |
| 12 | 25 | 25 | 30 | 30 | 20 | 20 | 25 | 25 | 12 |
| 10 | 30 | 35 | 40 | 40 | 25 | 30 | 30 | 35 | 10 |
| 8 | 40 | 50 | 55 | 55 | 30 | 40 | 40 | 45 | 8 |
| 6 | 55 | 65 | 70 | 75 | 40 | 50 | 55 | 60 | 6 |
| 4 | 70 | 85 | 95 | 95 | 55 | 65 | 75 | 75 | 4 |
| 3 | 85 | 100 | 110 | 110 | 65 | 75 | 85 | 85 | 3 |
| 2 | 95 | 115 | 125 | 130 | 75 | 90 | 100 | 100 | 2 |
| 1 | 110 | 130 | 145 | 150 | 85 | 100 | 110 | 115 | 1 |
| 0 | 125 | 150 | 165 | 170 | 100 | 120 | 130 | 135 | 0 |
| 00 | 145 | 175 | 190 | 195 | 115 | 135 | 145 | 150 | 00 |
| 000 | 165 | 200 | 215 | 225 | 130 | 155 | 170 | 175 | 000 |
| 0000 | 195 | 230 | 250 | 260 | 150 | 180 | 195 | 205 | 0000 |
| 250 | 215 | 255 | 275 | 290 | 170 | 205 | 220 | 230 | 250 |
| 300 | 240 | 285 | 310 | 320 | 190 | 230 | 250 | 255 | 300 |
| 350 | 260 | 310 | 340 | 350 | 210 | 250 | 270 | 280 | 350 |
| 400 | 280 | 335 | 365 | 380 | 225 | 270 | 295 | 305 | 400 |
| 500 | 320 | 380 | 415 | 430 | 260 | 310 | 335 | 350 | 500 |
| 600 | 355 | 420 | 460 | 475 | 285 | 340 | 370 | 385 | 600 |
| 700 | 385 | 460 | 500 | 520 | 310 | 375 | 405 | 420 | 700 |
| 750 | 400 | 475 | 515 | 535 | 320 | 385 | 420 | 435 | 750 |
| 800 | 410 | 490 | 535 | 555 | 330 | 395 | 430 | 450 | 800 |
| 900 | 435 | 520 | 565 | 585 | 355 | 425 | 465 | 480 | 900 |
| 1000 | 455 | 545 | 590 | 615 | 375 | 445 | 485 | 500 | 1000 |
| 1250 | 495 | 590 | 640 | 665 | 405 | 485 | 525 | 545 | 1250 |
| 1500 | 520 | 625 | 680 | 705 | 435 | 520 | 565 | 585 | 1500 |
| 1750 | 545 | 650 | 705 | 735 | 455 | 545 | 595 | 615 | 1750 |
| 2000 | 560 | 665 | 725 | 750 | 470 | 560 | 610 | 630 | 2000 |

## ENGLISH / METRIC CONVERSIONS

The following table shows some frequently used English / Metric conversions.

| UNIT | MULTIPLIED BY | EQUALS |
|---|---|---|
| AREA — | | |
| $in^2$ | 6.4516 | $cm^2$ |
| $ft^2$ | 0.0929 | $m^2$ |
| ENERGY — | | |
| Btu | 1054.8 | J |
| Btu | 778.3 | ft-lb |
| hp-hr | 2547 | Btu |
| kW-hr | 3416 | Btu |
| FLOW — | | |
| gpm | 3.785 | L/min |
| FORCE — | | |
| lb (force) | 4.448 | N |
| kg (force) | 9.807 | N |
| LENGTH — | | |
| in. | 25.4 | mm |
| ft | 0.30448 | m |
| yd | 0.9144 | m |
| mile | 5280 | ft |
| mile (nautical) | 6076.115 | ft |
| MASS / WEIGHT — | | |
| lb | 0.45359 | kg |
| lb (mass) | 453.59 | g |
| ton (long) | 2240 | lb |
| ton (metric) | 2205 | lb |
| ton (metric) | 1000 | kg |
| ton (short) | 2000 | lb |
| MISCELLANEOUS — | | |
| gal $H_20$ | 8.3453 | lb $H_20$ |
| | | |
| | | |
| | | |
| | | |

| UNIT | MULTIPLIED BY | EQUALS |
|---|---|---|
| POWER — | | |
| Btu/min | 12.96 | ft-lb/s |
| Btu/min | 17.57 | W |
| ft-lb/s | 1.356 | W |
| hp | 0.7457 | kW |
| hp | 44.24 | Btu/min |
| hp (metric) | 0.7355 | kW |
| hp (metric) | 542.5 | ft-lb/s |
| PRESSURE — | | |
| atmosphere | 1.013 | bar |
| atmosphere | 29.92 | in.Hg |
| atmosphere | 14.7 | psi |
| in. Hg (Mercury) | 13.596 | in. $H_20$ |
| in. Hg | 3.386 | kPa |
| in. $H_20$ | 0.249 | kPa |
| psi | 27.7 | in $H_20$ |
| psi | 2.037 | in. Hg |
| psi | 6.895 | kPa |
| bar | 100 | kPa |
| TEMPERATURE — | | |
| ˚C = (˚F-32)/1.8, or ˚C = ˚K-273.15 | | |
| ˚F = (˚Cx1.8)+32, or ˚K = ˚C+273.15 | | |
| ˚K = (˚F+459.67)/1.8 | | |
| TORQUE — | | |
| lb-ft | 1.356 | N•m |
| lb-in | 0.1130 | N•m |
| VOLUME — | | |
| gal | 231 | $in^3$ |
| gal | 3.785 | L |
| $in^3$ | 16.387 | $cm^3$ |
| ounce (fluid) | 29.57 | ml |
| quart | 0.946 | L |

ENGLISH / METRIC CONVERSIONS

# Technical Data

## AWG/METRIC CONDUCTOR CHART

| RESISTANCE | | | | CIRCULAR | | | WEIGHT | | D.C. RESISTANCE | D.C. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | APPROX. | O.D. | MIL | SQUARE | | | LBS./ | OHMS/ | OHMS/ |
| AWG | STRANDING | INCHES | MM | AREA | INCHES | MM | 1000 FT. | KG/KM | 1000 FT. | K/M |
| 36 | Solid | .0050 | 0.127 | 25.0 | — | 0.013 | .076 | .113 | 445.0 | 1460.0 |
| 36 | 7/44 | .006 | 0.152 | 28.0 | — | 0.014 | .085 | .126 | 371.0 | 1271.0 |
| 34 | Solid | .0063 | 0.160 | 39.7 | — | 0.020 | .120 | .179 | 280.0 | 918.0 |
| 34 | 7/42 | .0075 | 0.192 | 43.8 | — | 0.022 | .132 | .196 | 237.0 | 777.0 |
| 32 | Solid | .008 | 0.203 | 67.3 | .0001 | 0.032 | .194 | .289 | 174.0 | 571.0 |
| 32 | 7/40 | .008 | 0.203 | 67.3 | .0001 | 0.034 | .203 | .302 | 164.0 | 538.0 |
| 32 | 19/44 | .009 | 0.299 | 76.0 | .0001 | 0.039 | .230 | .342 | 136.0 | 448.0 |
| 30 | Solid | .010 | 0.254 | 100.0 | .0001 | 0.051 | .30 | .45 | 113.0 | 365.0 |
| 30 | 7/38 | .012 | 0.305 | 112.0 | .0001 | 0.057 | .339 | .504 | 103.0 | 339.0 |
| 30 | 19/42 | .012 | 0.305 | 118.8 | .0001 | 0.061 | .359 | .534 | 87.3 | 286.7 |
| 28 | Solid | .013 | 0.330 | 159.0 | .0001 | 0.080 | .48 | .72 | 70.8 | 232.0 |
| 28 | 7/36 | .015 | 0.381 | 175.0 | .0001 | 0.072 | .529 | .787 | 64.9 | 213.0 |
| 28 | 19/40 | .016 | 0.406 | 182.6 | .0001 | 0.093 | .553 | .823 | 56.7 | 186.0 |
| 27 | 7/35 | .018 | 0.457 | 219.5 | .0002 | 0.112 | .664 | .988 | 54.5 | 179.0 |
| 26 | Solid | .016 | 0.409 | 256.0 | .0002 | 0.128 | .770 | 1.14 | 43.6 | 143.0 |
| 26 | 10/36 | .021 | 0.533 | 250.0 | .0002 | 0.128 | .757 | 1.13 | 41.5 | 137.0 |
| 26 | 19/38 | .020 | 0.508 | 304.0 | .0002 | 0.155 | .920 | 1.37 | 34.4 | 113.0 |
| 26 | 7/34 | .019 | 0.483 | 277.8 | .0002 | 0.142 | .841 | 1.25 | 37.3 | 122.0 |
| 24 | Solid | .020 | 0.511 | 404.0 | .0003 | 0.205 | 1.22 | 1.82 | 27.3 | 89.4 |
| 24 | 7/32 | .024 | 0.610 | 448.0 | .0004 | 0.229 | 1.36 | 2.02 | 23.3 | 76.4 |
| 24 | 10/34 | .023 | 0.582 | 396.9 | .0003 | 0.202 | 1.20 | 1.79 | 26.1 | 85.6 |
| 24 | 19/36 | .024 | 0.610 | 475.0 | .0004 | 0.242 | 1.43 | 2.13 | 21.1 | 69.2 |
| 24 | 11/40 | .023 | 0.582 | 384.4 | .0003 | 0.196 | 1.16 | 1.73 | 25.6 | 84.0 |
| 22 | Solid | .025 | 0.643 | 640.0 | .0005 | 0.324 | 1.95 | 2.91 | 16.8 | 55.3 |
| 22 | 7/30 | .030 | 0.762 | 700.0 | .0006 | 0.357 | 2.12 | 3.16 | 14.7 | 48.4 |
| 22 | 19/34 | .031 | 0.787 | 754.1 | .0006 | 0.385 | 2.28 | 3.39 | 13.7 | 45.1 |
| 22 | 26/36 | .030 | 0.762 | 650.0 | .0005 | 0.332 | 1.97 | 2.93 | 15.9 | 52.3 |
| 20 | Solid | .032 | 0.813 | 1020.0 | .0008 | 0.519 | 3.10 | 4.61 | 10.5 | 34.6 |
| 20 | 7/28 | .038 | 0.965 | 1111.0 | .0009 | 0.562 | 3.49 | 5.19 | 10.3 | 33.8 |
| 20 | 10/30 | .035 | 0.889 | 1000.0 | .0008 | 0.510 | 3.03 | 4.05 | 10.3 | 33.9 |
| 20 | 19/32 | .037 | 0.940 | 1216.0 | .0010 | 0.620 | 3.70 | 5.48 | 8.6 | 28.3 |
| 20 | 26/34 | .036 | 0.914 | 1031.9 | .0008 | 0.526 | 3.12 | 4.64 | 10.0 | 33.0 |
| 20 | 41/36 | .036 | 0.914 | 1025.0 | .0008 | 0.523 | 3.10 | 4.61 | 10.0 | 32.9 |
| 18 | Solid | .040 | 1.020 | 1620.0 | .0013 | 0.823 | 4.92 | 7.32 | 6.6 | 21.8 |
| 18 | 7/26 | .048 | 1.219 | 1769.6 | .0014 | 0.902 | 5.36 | 7.98 | 5.9 | 19.2 |
| 18 | 16/30 | .047 | 1.194 | 1600.0 | .0013 | 0.816 | 4.84 | 7.20 | 8.5 | 21.3 |
| 18 | 19/30 | .049 | 1.245 | 1900.0 | .0015 | 0.969 | 5.75 | 8.56 | 5.5 | 17.9 |
| 18 | 41/34 | .047 | 1.194 | 1627.3 | .0013 | 0.830 | 4.92 | 7.32 | 6.4 | 20.9 |
| 18 | 65/36 | .047 | 1.194 | 1625.0 | .0013 | 0.829 | 4.91 | 7.31 | 6.4 | 21.0 |
| 16 | Solid | .051 | 1.290 | 2580.0 | .0020 | 1.310 | 7.81 | 11.60 | 4.2 | 13.7 |
| 16 | 7/24 | .060 | 1.524 | 2828.0 | .0022 | 1.442 | 8.56 | 12.74 | 3.7 | 12.0 |
| 16 | 65/34 | .059 | 1.499 | 2579.9 | .0020 | 1.316 | 7.81 | 11.62 | 4.0 | 13.2 |
| 16 | 26/30 | .059 | 1.499 | 2600.0 | .0021 | 1.326 | 7.87 | 11.71 | 4.0 | 13.1 |
| 16 | 19/29 | .058 | 1.473 | 2426.3 | .0019 | 1.327 | 7.35 | 10.94 | 4.3 | 14.0 |
| 16 | 105/36 | .059 | 1.499 | 2625.0 | .0021 | 1.339 | 7.95 | 11.83 | 4.0 | 13.1 |
| 14 | Solid | .064 | 1.630 | 4110.0 | .0032 | 2.080 | 12.40 | 18.50 | 2.6 | 8.6 |
| 14 | 7/22 | .073 | 1.854 | 4480.0 | .0035 | 2.285 | 13.56 | 20.18 | 2.3 | 7.6 |
| 14 | 19/27 | .073 | 1.854 | 3830.4 | .0030 | 1.954 | 11.59 | 17.25 | 2.7 | 8.9 |
| 14 | 41/30 | .073 | 1.854 | 4100.0 | .0032 | 2.091 | 12.40 | 18.45 | 2.5 | 8.3 |
| 14 | 105/34 | .073 | 1.854 | 4167.5 | .0033 | 2.125 | 12.61 | 18.77 | 2.5 | 8.2 |

# Technical Data

## AWG/METRIC CONDUCTOR CHART

| RESISTANCE | | | | CIRCULAR | | | WEIGHT | | D.C. RESISTANCE | D.C. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | APPROX. | O.D. | MIL | SQUARE | | | LBS./ | OHMS/ | OHMS/ |
| AWG | STRANDING | INCHES | MM | AREA | INCHES | MM | 1000 FT. | KG/KM | 1000 FT. | K/M |
| 12 | Solid | .081 | 2,05 | 6,530.0 | .0052 | 3,31 | 19.80 | 29.50 | 1.7 | 5.4 |
| 12 | 7/20 | .096 | 2,438 | 7,168.0 | .0057 | 3,66 | 21.69 | 32.28 | 1.5 | 4.8 |
| 12 | 19/25 | .093 | 2,369 | 6,087.6 | .0048 | 3,105 | 18.43 | 27.43 | 1.7 | 5.6 |
| 12 | 65/30 | .095 | 2,413 | 6,500.0 | .0051 | 3,315 | 19.66 | 29.26 | 1.8 | 5.7 |
| 12 | 165/34 | .095 | 2,413 | 6,548.9 | .0052 | 3,340 | 19.82 | 29.49 | 1.6 | 5.2 |
| 10 | Solid | .102 | 2,59 | 1,038.0 | .0083 | 5,26 | 31.4 | 46.80 | 1.0 | 3.4 |
| 10 | 37/26 | .115 | 2,921 | 9,353.6 | .0074 | 4,770 | 28.31 | 41.13 | 1.1 | 3.6 |
| 10 | 49/27 | .116 | 2,946 | 9,878.4 | .0078 | 5,038 | 29.89 | 44.48 | 1.1 | 3.6 |
| 10 | 105/30 | .116 | 2,946 | 10,530.0 | .0083 | 5,370 | 31.76 | 47.26 | 0.98 | 3.2 |
| 8 | 49/25 | .147 | 3,374 | 15,697.0 | .0124 | 8,007 | 47.53 | 70.73 | 0.67 | 2.2 |
| 8 | 133/29 | .147 | 3,374 | 16,984.0 | .0134 | 8,662 | 51.42 | 76.52 | 0.61 | 2.0 |
| 8 | 655/36 | .147 | 3,374 | 16,625.0 | .0131 | 8,479 | 49.58 | 73.78 | 0.62 | 2.0 |
| 6 | 133/27 | .184 | 4,674 | 26,813.0 | .0212 | 13,675 | 81.14 | 120.74 | 0.47 | 1.5 |
| 6 | 259/30 | .184 | 4,674 | 25,900.0 | .0205 | 13,209 | 78.35 | 116.59 | 0.40 | 1.3 |
| 6 | 1050/36 | .184 | 4,674 | 26,250.0 | .0208 | 13,388 | 79.47 | 118.26 | 0.39 | 1.3 |
| 4 | 133/25 | .232 | 5,898 | 42,613.0 | .0337 | 21,733 | 129.01 | 191.98 | 0.24 | 0.80 |
| 4 | 259/27 | .232 | 5,898 | 52,214.0 | .0413 | 26,629 | 158.02 | 235.15 | 0.20 | 0.66 |
| 4 | 1666/36 | .232 | 5,898 | 41,650.0 | .0329 | 21,242 | 126.10 | 187.65 | 0.25 | 0.82 |
| 2 | 133/23 | .292 | 7,417 | 67,936.0 | .0537 | 34,648 | 205.62 | 305.98 | 0.15 | 0.50 |
| 2 | 259/26 | .292 | 7,417 | 65,475.0 | .0518 | 33,392 | 198.14 | 294.85 | 0.16 | 0.52 |
| 2 | 665/30 | .292 | 7,417 | 66,500.0 | .0526 | 33,915 | 201.16 | 299.35 | 0.16 | 0.52 |
| 2 | 2646/36 | .292 | 7,417 | 66,150.0 | .0523 | 33,737 | 200.28 | 298.04 | 0.16 | 0.52 |
| 1 | 163,195.9 | .328 | 8,331 | 85,133.0 | .0673 | 43,418 | 257.60 | 383.34 | 0.12 | 0.40 |
| 1 | 172,508.0 | .328 | 8,331 | 82,984.0 | .0656 | 42,322 | 251.20 | 373.81 | 0.13 | 0.41 |
| 1 | 817/30 | .328 | 8,331 | 81,700.0 | .0646 | 41,667 | 247.10 | 367.71 | 0.13 | 0.42 |
| 1 | 2109/34 | .328 | 8,331 | 83,706.0 | .0662 | 42,690 | 253.29 | 376.92 | 0.12 | 0.41 |
| 1/0 | 133/21 | .368 | 9,347 | 108,036.0 | .0854 | 55,098 | 327.05 | 486.68 | 0.096 | 0.31 |
| 1/0 | 259/24 | .368 | 9,347 | 104,636.0 | .0827 | 53,364 | 316.76 | 471.37 | 0.099 | 0.32 |
| 2/0 | 133/20 | .414 | 10,516 | 136,192.0 | .1077 | 69,458 | 412.17 | 613.35 | 0.077 | 0.25 |
| 2/0 | 259/23 | .414 | 10,516 | 132,297.0 | .1046 | 67,472 | 400.41 | 595.85 | 0.077 | 0.25 |
| 3/0 | 259/22 | .464 | 11,786 | 163,195.0 | .1290 | 83.230 | 501.70 | 746.58 | 0.062 | 0.20 |
| 3/0 | 427/24 | .464 | 11,786 | 172,508.0 | .1364 | 87,979 | 522.20 | 777.09 | 0.059 | 0.19 |
| 4/0 | 259/21 | .522 | 13,259 | 210,386.0 | .1663 | 107,297 | 638.88 | 950.72 | 0.049 | 0.16 |
| 4/0 | 427/23 | .522 | 13,259 | 218,112.0 | .1724 | 111,237 | 660.01 | 982.16 | 0.047 | 0.15 |

# Time and Speed Table

If you know the time of your boat over a statute or nautical mile, this table shows the corresponding speed in statute or nautical miles per hour.

| Secs. | 1 min. | 2 min. | 3 min. | 4 min. | 5 min. | 6 min. | 7 min. | 8 min. | 9 min. | 10 min. | 11 min. | 12 min. | 13 min. | 14 min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 60.000 | 30.000 | 20.000 | 15.000 | 12.000 | 10.000 | 8.571 | 7.500 | 6.667 | 6.000 | 5.455 | 5.000 | 4.615 | 4.286 |
| 1 | 59.016 | 29.752 | 19.890 | 14.938 | 11.960 | 9.972 | 8.551 | 7.484 | 6.654 | 5.990 | 5.446 | 4.993 | 4.609 | 4.281 |
| 2 | 58.064 | 29.508 | 19.780 | 14.876 | 11.921 | 9.945 | 8.531 | 7.469 | 6.642 | 5.980 | 5.438 | 4.986 | 4.604 | 4.275 |
| 3 | 57.143 | 29.268 | 19.672 | 14.815 | 11.881 | 9.917 | 8.511 | 7.453 | 6.630 | 5.970 | 5.430 | 4.979 | 4.598 | 4.270 |
| 4 | 56.250 | 29.032 | 19.565 | 14.754 | 11.842 | 9.890 | 8.491 | 7.438 | 6.618 | 5.960 | 5.422 | 4.972 | 4.592 | 4.265 |
| 5 | 55.384 | 28.800 | 19.459 | 14.694 | 11.803 | 9.863 | 8.471 | 7.423 | 6.606 | 5.950 | 5.414 | 4.965 | 4.586 | 4.260 |
| 6 | 54.545 | 28.571 | 19.355 | 14.634 | 11.765 | 9.836 | 8.451 | 7.407 | 6.593 | 5.941 | 5.405 | 4.959 | 4.580 | 4.255 |
| 7 | 53.731 | 28.346 | 19.251 | 14.575 | 11.726 | 9.809 | 8.431 | 7.392 | 6.581 | 5.931 | 5.397 | 4.952 | 4.574 | 4.250 |
| 8 | 52.941 | 28.125 | 19.149 | 14.516 | 11.688 | 9.783 | 8.411 | 7.377 | 6.569 | 5.921 | 5.389 | 4.945 | 4.568 | 4.245 |
| 9 | 52.174 | 27.907 | 19.048 | 14.458 | 11.650 | 9.756 | 8.392 | 7.362 | 6.557 | 5.911 | 5.381 | 4.938 | 4.563 | 4.240 |
| 10 | 51.428 | 27.692 | 18.947 | 14.400 | 11.613 | 9.730 | 8.372 | 7.347 | 6.545 | 5.902 | 5.373 | 4.931 | 4.557 | 4.235 |
| 11 | 50.704 | 27.481 | 18.848 | 14.343 | 11.576 | 9.704 | 8.353 | 7.332 | 6.534 | 5.892 | 5.365 | 4.925 | 4.551 | 4.230 |
| 12 | 50.000 | 27.273 | 18.750 | 14.286 | 11.538 | 9.677 | 8.333 | 7.317 | 6.522 | 5.882 | 5.357 | 4.918 | 4.545 | 4.225 |
| 13 | 49.315 | 27.068 | 18.653 | 14.229 | 11.502 | 9.651 | 8.314 | 7.302 | 6.510 | 5.873 | 5.349 | 4.911 | 4.540 | 4.220 |
| 14 | 48.648 | 26.866 | 18.557 | 14.173 | 11.465 | 9.626 | 8.295 | 7.287 | 6.498 | 5.863 | 5.341 | 4.905 | 4.534 | 4.215 |
| 15 | 48.000 | 26.667 | 18.461 | 14.118 | 11.429 | 9.600 | 8.276 | 7.273 | 6.486 | 5.854 | 5.333 | 4.898 | 4.528 | 4.210 |
| 16 | 47.368 | 26.471 | 18.367 | 14.062 | 11.392 | 9.574 | 8.257 | 7.258 | 6.475 | 5.844 | 5.325 | 4.891 | 4.523 | 4.206 |
| 17 | 46.753 | 26.277 | 18.274 | 14.008 | 11.356 | 9.549 | 8.238 | 7.243 | 6.463 | 5.835 | 5.318 | 4.885 | 4.517 | 4.201 |
| 18 | 46.154 | 26.087 | 18.182 | 13.953 | 11.321 | 9.524 | 8.219 | 7.229 | 6.452 | 5.825 | 5.310 | 4.878 | 4.511 | 4.196 |
| 19 | 45.570 | 25.899 | 18.090 | 13.900 | 11.285 | 9.499 | 8.200 | 7.214 | 6.440 | 5.816 | 5.302 | 4.871 | 4.506 | 4.191 |
| 20 | 45.000 | 25.714 | 18.000 | 13.846 | 11.250 | 9.474 | 8.182 | 7.200 | 6.429 | 5.806 | 5.294 | 4.865 | 4.500 | 4.186 |
| 21 | 44.444 | 25.532 | 17.910 | 13.793 | 11.215 | 9.449 | 8.163 | 7.186 | 6.417 | 5.797 | 5.286 | 4.858 | 4.494 | 4.181 |
| 22 | 43.902 | 25.352 | 17.822 | 13.740 | 11.180 | 9.424 | 8.145 | 7.171 | 6.406 | 5.788 | 5.279 | 4.852 | 4.489 | 4.176 |
| 23 | 43.373 | 25.175 | 17.734 | 13.688 | 11.146 | 9.399 | 8.126 | 7.157 | 6.394 | 5.778 | 5.271 | 4.845 | 4.483 | 4.171 |
| 24 | 42.857 | 25.000 | 17.647 | 13.636 | 11.111 | 9.375 | 8.108 | 7.143 | 6.383 | 5.769 | 5.263 | 4.839 | 4.478 | 4.167 |
| 25 | 42.353 | 24.828 | 17.561 | 13.585 | 11.077 | 9.351 | 8.090 | 7.129 | 6.372 | 5.760 | 5.255 | 4.832 | 4.472 | 4.162 |
| 26 | 41.860 | 24.658 | 17.475 | 13.534 | 11.043 | 9.326 | 8.072 | 7.115 | 6.360 | 5.751 | 5.248 | 4.826 | 4.467 | 4.157 |
| 27 | 41.379 | 24.490 | 17.391 | 13.483 | 11.009 | 9.302 | 8.054 | 7.101 | 6.349 | 5.742 | 5.240 | 4.819 | 4.461 | 4.152 |
| 28 | 40.909 | 24.324 | 17.308 | 13.433 | 10.976 | 9.278 | 8.036 | 7.087 | 6.338 | 5.732 | 5.233 | 4.813 | 4.455 | 4.147 |
| 29 | 40.450 | 24.161 | 17.225 | 13.383 | 10.942 | 9.254 | 8.018 | 7.073 | 6.327 | 5.723 | 5.225 | 4.806 | 4.450 | 4.143 |
| 30 | 40.000 | 24.000 | 17.143 | 13.333 | 10.909 | 9.231 | 8.000 | 7.059 | 6.316 | 5.714 | 5.217 | 4.800 | 4.444 | 4.138 |
| 31 | 39.561 | 23.841 | 17.062 | 13.284 | 10.876 | 9.207 | 7.982 | 7.045 | 6.305 | 5.705 | 5.210 | 4.794 | 4.439 | 4.133 |
| 32 | 39.130 | 23.684 | 16.981 | 13.235 | 10.843 | 9.184 | 7.965 | 7.031 | 6.294 | 5.696 | 5.202 | 4.787 | 4.433 | 4.128 |
| 33 | 38.710 | 23.529 | 16.901 | 13.187 | 10.811 | 9.160 | 7.947 | 7.018 | 6.283 | 5.687 | 5.195 | 4.781 | 4.428 | 4.124 |
| 34 | 38.298 | 23.377 | 16.822 | 13.139 | 10.778 | 9.137 | 7.930 | 7.004 | 6.272 | 5.678 | 5.187 | 4.774 | 4.423 | 4.119 |
| 35 | 37.895 | 23.226 | 16.744 | 13.091 | 10.746 | 9.114 | 7.912 | 6.990 | 6.261 | 5.669 | 5.150 | 4.768 | 4.417 | 4.114 |
| 36 | 37.500 | 23.077 | 163667 | 13.043 | 10.714 | 9.091 | 7.895 | 6.977 | 6.250 | 5.660 | 5.172 | 4.762 | 4.412 | 4.110 |
| 37 | 37.113 | 22.930 | 16.590 | 12.996 | 10.652 | 9.068 | 7.877 | 6.963 | 6.239 | 5.651 | 5.165 | 4.756 | 4.406 | 4.105 |
| 38 | 36.736 | 22.785 | 16.514 | 12.950 | 10.651 | 9.045 | 7.860 | 6.950 | 6.228 | 5.643 | 5.158 | 4.749 | 4.401 | 4.100 |
| 39 | 36.364 | 22.642 | 16.438 | 12.903 | 10.619 | 9.023 | 7.843 | 6.936 | 6.218 | 5.634 | 5.150 | 4.743 | 4.396 | 4.096 |
| 40 | 36.000 | 22.500 | 16.364 | 12.857 | 10.588 | 9.000 | 7.826 | 6.923 | 6.207 | 5.625 | 5.143 | 4.737 | 4.390 | 4.091 |
| 41 | 35.644 | 22.360 | 12.290 | 12.811 | 10.557 | 8.978 | 7.809 | 6.910 | 6.196 | 5.616 | 5.136 | 4.731 | 4.385 | 4.086 |
| 42 | 35.294 | 22.222 | 16.216 | 12.766 | 10.526 | 8.955 | 7.792 | 6.897 | 6.186 | 5.607 | 5.128 | 4.724 | 4.379 | 4.082 |
| 43 | 34.951 | 22.086 | 16.143 | 12.721 | 10.496 | 8.933 | 7.775 | 6.883 | 6.175 | 5.599 | 5.121 | 4.718 | 4.374 | 4.077 |
| 44 | 34.615 | 21.951 | 16.071 | 12.676 | 10.465 | 8.911 | 7.759 | 6.870 | 6.164 | 5.590 | 5.114 | 4.712 | 4.369 | 4.072 |
| 45 | 34.286 | 21.818 | 16.000 | 12.635 | 10.435 | 8.889 | 7.742 | 6.857 | 6.154 | 5.581 | 5.106 | 4.706 | 4.364 | 4.068 |
| 46 | 33.962 | 21.687 | 15.929 | 12.587 | 10.405 | 8.867 | 7.725 | 6.844 | 6.143 | 5.573 | 5.099 | 4.700 | 4.358 | 4.063 |
| 47 | 33.644 | 21.557 | 15.859 | 12.544 | 10.375 | 8.845 | 7.709 | 6.831 | 6.133 | 5.564 | 5.092 | 4.893 | 4.353 | 4.059 |
| 48 | 33.333 | 21.429 | 15.789 | 12.500 | 10.345 | 8.824 | 7.692 | 6.818 | 6.122 | 5.556 | 5.085 | 4.687 | 4.348 | 4.054 |
| 49 | 33.028 | 21.302 | 15.721 | 12.457 | 10.315 | 8.802 | 7.676 | 6.805 | 6.112 | 5.547 | 5.078 | 4.681 | 4.343 | 4.049 |
| 50 | 32.727 | 21.176 | 15.652 | 12.414 | 10.286 | 8.780 | 7.660 | 6.792 | 6.102 | 5.538 | 5.070 | 4.675 | 4.337 | 4.045 |
| 51 | 32.432 | 21.053 | 15.584 | 12.371 | 10.256 | 8.759 | 7.643 | 6.780 | 6.091 | 5.530 | 5.063 | 4.669 | 4.332 | 4.040 |
| 52 | 32.143 | 20.930 | 15.517 | 12.329 | 10.227 | 8.738 | 7.627 | 6.767 | 6.081 | 5.521 | 5.056 | 4.663 | 4.327 | 4.035 |
| 53 | 31.858 | 20.809 | 15.451 | 12.287 | 10.198 | 8.717 | 7.611 | 6.754 | 6.071 | 5.513 | 5.049 | 4.657 | 4.322 | 4.031 |
| 54 | 31.579 | 20.690 | 15.385 | 12.245 | 10.169 | 8.696 | 7.595 | 6.742 | 6.061 | 5.505 | 5.042 | 4.651 | 4.316 | 4.027 |
| 55 | 31.304 | 20.571 | 15.319 | 12.203 | 10.141 | 8.675 | 7.579 | 6.729 | 6.050 | 5.496 | 5.035 | 4.645 | 4.311 | 4.022 |
| 56 | 31.034 | 20.455 | 15.254 | 12.162 | 10.112 | 8.654 | 7.563 | 6.716 | 6.040 | 5.488 | 5.028 | 4.639 | 4.306 | 4.018 |
| 57 | 30.769 | 20.339 | 15.190 | 12.121 | 10.084 | 8.633 | 7.547 | 6.704 | 6.030 | 5.479 | 5.021 | 4.633 | 4.301 | 4.013 |
| 58 | 30.508 | 20.225 | 15.126 | 12.081 | 10.056 | 8.612 | 7.531 | 6.691 | 6.020 | 5.471 | 5.014 | 4.627 | 4.296 | 4.009 |
| 59 | 30.252 | 20.112 | 15.063 | 12.040 | 10.028 | 8.592 | 7.516 | 6.679 | 6.010 | 5.463 | 5.007 | 4.621 | 4.291 | 4.004 |

# Glossary - Electrical Terms

**AC** -Alternating current, which varies from zero to a positive maximum to zero to a negative maximum to zero, a number of times per second, the number being expressed in cycles per second or Hertz.

**Air gap** - The radial space between the rotating element and the stationary element of a generator or motor, through which space the magnetic energy passes.

**Alternator** - A generator which produces alternating current.

**Ambient temperature** - The temperature of the surroundings in which a generator operates. Assumed to be 40˚ C maximum unless otherwise stated.

**Ammeter** - An instrument designed to measure electric current flow.

**Amortisseur** - A short-circuited winding in the rotor of a synchronous generator, consisting of conductors embedded in the pole faces, connected together at both ends of the poles by end rings. Its function is to damp out oscillations or hunting during load changes.

**Ampere** - The unit of electric current flow. One ampere will flow when one bolt is applied across a resistance of one ohm.

**Ampere turn** - A unit of magneto-motive force. The product of current flowing multiplied by the number of turns in a coil.

**Armature** - An armature is the complete assembly of armature winding and armature core. In Northern Lights synchronous generators it is the stationary part with the stator windings.

**Armature coil** - The stator windings embedded in the core, in which the voltage is induced.

**Armature core** - The magnetic steel laminations of the armature.

**Auto-transformer** - A transformer of single coil construction in which both primary and secondary connections are made to the same coil at different taps.

**B -** - The negative polarity of a storage battery.

**B +** - The positive polarity of a storage battery.

**Capacitance** - The property of a capacitor (or condenser) which causes the current to lead the voltage, thereby creating a leading power factor (see power factor).

**Capacitor** - A device capable of storing electric energy consisting of tow conducting surfaces separated by an insulating material. It blocks the flow of direct current while allowing alternating current to pass.

**Circuit** - A path for an electric current.

**Circuit Breaker** - A switching device for opening and closing an electric circuit.

**Condenser** - See capacitor.

**Conductor** - A wire or cable for carrying current.

**Connector** - A device for electrically interconnecting two or more conductors.

**Contactor** - A device for establishing and breaking an electric power circuit.

**Controlled rectifier** - See SCR.

**Copper loss** - That portion of the losses involved in generation caused by the flow of current through coils and conductors within the generator, proportional to the resistance and to the square of the current.

**Core** - The laminations in the generator constituting the magnetic structure thereof.

**Cross current compensation** - In parallel operation of generators, a system which permits the generators to share the reactive component of the power in proportion to their rating.

**CT or current transformer** - A transformer, generally with a 5 ampere secondary, used in conjunction with control circuits and instruments such as ammeters and watt meters.

**Current** - The flow of electric power expressed in amperes.

**Current limiting fuse** - A specially designed fuse which will interrupt a circuit practically instantaneously when the current reaches a certain value, but will not do so below that value, regardless of its duration.

**Cycle** - One complete reversal of an alternating current or voltage, from zero to a positive maximum to zero to a negative maximum back to zero. The number of cycles per second is the frequency, expressed in Hertz (hz).

**Damper winding** - See amortisseur.

**DC** - see direct current.

**Decibel dB** - Unit used to describe noise level.

**Deviation factor** - A measure of the amount by which an alternating voltage differs from a pure sine wave.

**Dielectric** - Insulation.

**Dielectric strength** - The ability of insulation to withstand voltage without rupturing.

**Diode** - A two terminal solid-state device which allows current to flow in one direction, but not in the other. Since it allows only the positive half cycle of an alternating current to flow, its output will be unidirectional, for which reason it may be considered as a rectifying element.

**Direct current** - An electric current which flows in one direction only.

**Distribution panel** - The output of a generator is supplied to the distribution panel, where it is divided for supplying different loads. Generally contains circuit breakers and protective devices.

**Double pole switch** - A switch which opens or closes two circuits at the same time.

**Double throw switch** - A switch which has a normally open and a normally closed contact with a common terminal.

**DPDT switch** - A double pole, double throw switch.

**DPST switch** - A double pole, single throw switch.

**Drift** - A gradual change in voltage output, sometimes caused by an increase in temperature resulting from generator or regulator losses.

**Drop, voltage** - Voltage drop is caused by a current flowing through a resistance. It is equal to the current in amperes times the resistance in ohms.

**E** - Symbol used for voltage.

**Earth** - Electrical ground.

**Eddy current** - Current circulating in conducting materials, caused by magnetic fields. They represent losses in generators and are reduced by the use of thin laminations of special steel.

**Effective values** - The RMS (root means square) value of an AC value, such as voltage and current. The usual meters indicate these values.

**Efficiency** - The ratio between electrical output divided by the mechanical input, expressed as a percentage of the Efficiency = $\frac{\text{KW output}}{\text{HP input/0.746}}$

**Electrical angle** - One cycle, or the distance between two poles of the same polarity, contains 360 electrical degrees. Hence the electrical angle represents a certain point of the AC wave.

**Electrical degree** - One 360th part of a cycle of an alternating wave.

**Electrical radian** - A part of an alternating current or voltage cycle, a cycle contains 2 radians.

**Electro-magnetic field** - A magnetic field located at right angles to the lines of force and to their direction of motion.

**EMF** - See electro-motive force.

**EMI** - Electro-magnetic (radio) interference.

**End rings** - That part of the amortisseur winding which electrically interconnects the amortisseur bars of adjacent poles.

**Energy** - Capability of performing work. Expressed in KW-hrs.

**Excitation** - The input of DC power into the field coils of a synchronous generator, producing the magnetic flux required for inducing voltages in the armature coils.

**Exciter** - A device for supplying excitation to generator fields. It may be a rotating exciter, that is a DC generator or AC generator with rectifiers, or it may be a static device using solid-state components.

**Exciter current** - The field current required to produce rated voltage at rated load and frequency.

**Exciter voltage** - The voltage required to cause the exciter current to flow through the field winding.

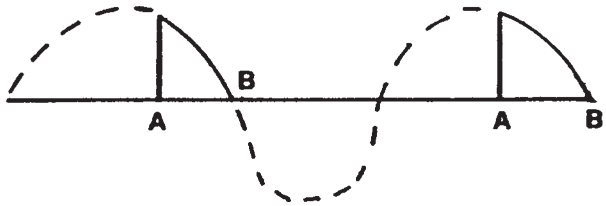
**Feedback** - Transfer of a portion of energy from one point in an electrical system to a preceding point, such as from the output back to the input, used to increase stability.

**Field** - That part of the generator rotor which, when supplied with direct current, will establish the magnetic field. Also, the magnetic field so produced.

**Field coil** - The coils of the rotating field structure being supplied with direct current for excitation.

**Field pole** - The part of the rotating magnetic structure of a generator on which the field coils are located.

**Firing circuit** - The circuit which controls the point within a cycle at which a voltage is applied to the gate of a silicon controlled rectifier (SCR) thereby allowing current to flow through the SCR. The SCR is a solid-state device which can pass a current in one direction only, similar to a diode. However, it has a third terminal, called the gate, and current can pass only when a suitable potential (voltage) is applied to the gate.




Gate voltage is applied at point A. The SCR will then pass current until the voltage becomes negative at B. When the voltage becomes positive again, no current can flow until the proper voltage is again applied at A. The firing circuit establishes point A in accordance with requirement. The area enclosed in the solid lines is thereby established in accordance with requirements determined by the voltage regulator. This area is proportional to the field excitation needed to maintain nominal voltage.

**Frame generator** - The mechanical element which contains the stator core and coils.

**Freewheeling diode** - A diode whose function is to allow the conduction of an inductive load current during those periods in which the SCR is in the non-conducting state.

**Frequency** - The number of complete cycles of an alternating voltage of current per unit of time, usually per second. So expressed in CPS, cycles per second, or Hertz (hz).

**Fundamental frequency** - A generator produces a voltage with a wave shape approaching a pure sine wave. Deviations from this sine wave can be expressed as additional sine waves of frequencies which are a multiple of the fundamental frequency. The additional frequencies are called harmonics. They are expressed as third, fifth, etc. harmonics, demoting their frequency as a multiple of the fundamental frequency. For example, in a 60 hz generator, 600 hz is the fundamental frequency. The third harmonic will have a frequency of 3 times 60 or 180 hz.

**Gain** - An amplification ratio obtained by dividing the change in an output quantity by a change in a corresponding input quantity.

**Gate** - The third terminal of a SCR to which a voltage must be applied before a current can pass from the first terminal to the second.

**Generator** - A machine which transforms mechanical energy into electrical energy.

**Ground** - A connection, either intentional or accidental, between an electric circuit and the earth or some conducting body serving in place of the earth.

**Grounded neutral** - The center point of a Y-connected, four-wire generator, which is intentionally connected to ground.

**Harmonic** - See fundamental frequency.

**Heat sink** - A device which absorbs and dissipates heat from diodes and SCR's to prevent damage caused by overheating.

**Hertz** - Equivalent to cycles per second (CPS). Symbol is hz (see cycle).

**Hunting** - A phenomenon occurring upon load changes, in which the frequency or the voltage continues to rise above and fall below the desired value and does not reach a steady-state value. Caused by insufficient damping.

**I** - Symbol for current, expressed in amperes.

**Induced voltage** - The voltage which is produced in a coil as it passes through a magnetic field when the number of magnetic lines of force cutting across the conductors changes.

**Inductance** - The property of a coil which tends to prevent a change in current flow when alternating currents are present. Expressed in Henrys.

**In phase** - Alternating currents and voltages are in phase when they pass through zero and reach their maximum simultaneously.

**Insulation** - Non-conductive material used to prevent leakage of electric power from a conductor. In generators, four classes of insulation are used and each class has its own maximum temperature that it can successfully withstand under continuous full load operation by resistance measurement.

**Class A** - 60˚C rise over a 40˚C ambient.

**Class B** - 80˚C rise over a 40˚C ambient.

**Class F** - Prime power duty: 105˚C rise over a 40˚C ambient. Standby power duty: 130˚C rise over a 40˚C ambient.

**Class H** - 125˚C rise over a 40˚C ambient.

**Insulation resistance** - The resistance, measured by a megohmmeter, between the generator leads and the generator frame and between the field leads and the shaft.

**IR voltage drop** - (across a resistance) Equal to the current in amperes times the resistance in ohms.

**Iron loss** - That portion of the losses involved in generation caused by the magnetization of the cores. It depends on the flux density and the thickness and material of the core lamination.

**K** - one 1000.

**KVA** - 1000 volt amperes (see VA).

**KVAR** - 1000 reactive volt amperes (see reactive KVA).

**KW** - Unit of electric power, equal to 1000 watts (see real power).

**KW hr.** - One KW of electric power used for 1 hour. Unit of electric energy.

**L** - Symbol for inductance express in Henrys.

**Lagging power factor** - Caused by inductive loads, such as motors and transformers, in which the current lags behind the voltage in an alternating current network (see power factor).

**Laminated core** - A ferromagnetic core, consisting of a number of thin laminations of silicon steel, forming the magnetic path in a generator.

**Line to line voltage** - The voltage existing between any two phases of a two or three phase generator.

**Losses** - The difference between the input and the output of an electrical or mechanical device.

**Magnetic circuit** - A path for magnetic lines of force.

**Magnetic field density** - Magnetic lines of force per unit area.

**Magnetic field strength** - The number of magnetic lines of force produced by field current.

**Magnetic line of force** - Imaginary lines used for convenience to designate the direction in which magnetic forces act in a magnetic field produced by the field windings of a generator.

**Megger** - A high range ohmmeter having a built-in hand operated generator used for measuring insulation resistance.

**Megohm** - One million ohms

**Megohmmeter** - See megger.

**Neutral** - The common point of a Y-connected machine, or a conductor connected to that point.

**NC or normally closed** - A relay contact which is closed when the relay coil is not energized.

**NO or normally open** - A relay contact which is open when the relay coil is not energized.

**Ohm** - Unit of electrical resistance. One volt will cause a current of one ampere to flow through a resistance of one ohm.

**Ohmmeter** - A device for measuring electrical resistance.

**Ohm's law** - A fundamental law expressing the relationship between voltage, current and resistance in DC circuits. In AC circuits a value called impedance replaces the DC resistance. The law states that E=IR, voltage is equal to current times resistance.

**Open circuit voltage** - The voltage produced when no load in attached to the voltage source, such as a generator.

**Oscillogram** - A trace of rapidly changing electric quantities recorded on an oscillograph.

**Oscillograph** - A recording oscilloscope.

**Oscilloscope** - A device, generally a cathode-ray tube, which reproduces on a viewing screen, traces of the wave shape of one or more rapidly changing quantities.

**Out-of-phase** - Waves of the same frequency which do not pass through their zero point at the same instant.

**Overload rating** - The load in excess of the nominal rating a generator set is designed to produce for a specified length of time.

**Overload relay** - A relay which operates to interrupt excessive currents.

**Parallel connection** - An electrical connection in which the input electrode of one element is connected to the input electrode of another element, and the output electrodes are similarly connected together, thereby providing two paths for current flow.

**Parallel operation** - Two or more generators of the same voltage and frequency characteristics connected to the same load.

**Paralleling** - The procedure used to connect two or more generators in parallel, that is, connect them to a common load.

**PF** - See power factor.

**Phase** - The windings of an AC generator. In a three-phase generator there are three windings with their voltages 120 degrees out of phase, meaning that the instants at which the three voltages pass through zero or reach their maximums are 120 degrees, if one complete cycle is considered to contain 360 degrees. In single-phase generators, only one winding is present.

**Phase rotation** - The sequence in which the phases of a generator or network pass through the zero points of their waves. The same sequence must exist when units are paralleled.

**Polarity** - An electrical property which indicates the direction in which a direct current tends to flow. Expressed as + and - or positive and negative.

**Pole** - A part of a magnetic structure, there being two such parts called a North pole and a South pole. Since neither pole can exist without the corresponding opposite, they always are present in pairs. Hence a generator always has an even number of poles. Also, used for the electrodes of a battery and to indicate the number of circuits affected by a switch.

**Potential** - Voltage.

**Potential difference** - The difference in voltage between two points.

**Potentiometer** - A variable resistor. A rheostat.

**Power** - Rate of performing work, or energy per unit of time. Mechanical power can be measured in horsepower, electrical power in kilowatts.

**Power factor (also cos ø)** - In AC circuits, the inductances and capacitances may cause the point at which the voltage wave passes through zero to differ from the point at which the current wave passes through zero. When the current wave precedes the voltage wave, a leading power factor results, as in the case of a capacitive load or over-excited synchronous motor. When the voltage wave precedes the current wave, a lagging power factor results, this is generally the case. The power factor expresses the extent to which the voltage zero differs from the current zero. Considering one full cycle to be 360 degrees, the difference between the zero points can then be expressed as an angle. Power factor is calculated as the cosine of the angle between zero points and is expressed as a decimal fraction (.8) or as a percentage (80%). It can also be shown to be the ratio of KW, divided by the KVA. In other words KW=KVA x PF (see power factor).

**Primary winding** - The winding of a transformer which is on the input side. The input winding, usually the stator of the generator may be referred to as the primary winding.

**R** - Symbol for resistance, expressed in ohms.

**Radio interference** - The interference with radio reception caused by a generator set.

**Radio interference suppression** - Filter to minimize radio interference.

**Reactance** - Opposition to current in AC applications, caused by inductances and capacitances. It is expressed in ohms and its symbol is X.

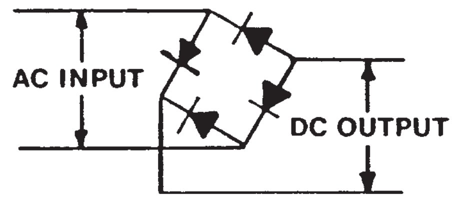
**Reactive KVA or KVAR (1000 reactive volt amperes)** - an AC value consists of active and wattless components. The active component is expressed in KW, the wattless component in KVAR. The result KVA is calculated from

$$KVA = \sqrt{KW^2 + KVAR^2}$$

**Real power** - A term used to describe the product of current, voltage and power factor, expressed in KW. One KW equals 1.34 HP.

**Reactifier** - A device for changing alternating current into direct current.

**Rectifier bridge** - A group of rectifiers (possibly diodes) connected in such a way that DC voltage appears across one diagonal when an AC voltage is applied across the other diagonal.




**Regulation, frequency** - A value obtained by dividing the difference between no load and full load frequency by the full load frequency. Expressed in percent.

**Regulation, voltage** - See voltage regulation.

**Regulator, voltage** - See voltage regulator.

**Relay** - An electro-magnetic device which opens or closes its contact and the circuits connected thereto under the influence of an impulse applied to its coil.

**Residual magnetism** - The magnetic induction which remains after the magnetization force is removed.

**Resistance** - The opposition to the flow of direct current, expressed in ohms and its symbol is R.

**Resistor** - A component which offers resistance to the flow of electric current. Its rating is expressed in ohms and watts, indicating the heat which it can dissipate.

**Resistor, variable** - A resistor with a means for adjusting its resistance value.

**Rheostat** - A resistor of which the resistance value can be changed by turning a knob, or a shaft with a screwdriver slot and locking nut. A potentiometer.

**Rotor** - The rotating element of a motor or generator.

**RPM** - Revolutions per minute.

**Secondary winding** - That part of a transformer to which the load in connected; it receives energy from the primary or input side through electro-magnetic induction.

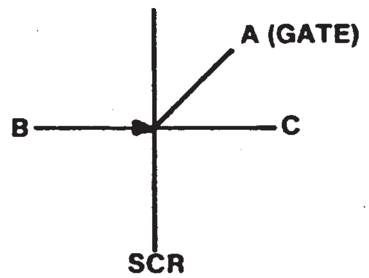
**Series connection** - An electrical connection in which the output electrode of one element is connected to the input electrode of another element, thereby providing one path for current flow.

**Short circuit** - Generally a non-intentional electrical connection between current carrying parts.

**Shunt trip** - An electro magnet which when energized trips a circuit breaker and thereby opens a circuit.

**Signal** - An electrical impulse which initiates action of a regulating device. Also called error signal, which in a voltage regulator denotes the difference between the sensed voltage and the reference voltage.

**SCR or silicon controlled rectifier (also see gate)** - A three terminal solid-state device which permits current to flow in one direction only and to do this only when a suitable potential is applied to the third terminal called the gate.




**Single phase** - A circuit or a device energized by a single alternating voltage. One phase of a polyphase system.

**Single pole switch** - A switch that opens or closes one contact.

**Single throw switch** - A switch that has a normally open or a normally closed contact.

**Speed droop** - Decrease in steady-state speed of an engine caused by increase in load from no load to full load without change in governor adjustment. This decrease in full load speed is expressed as a percent of mean speed or:

$$\frac{\text{(no load speed (NLS) — full load speed (FLS) x 100)}}{\text{full load speed}}$$

**Solenoid** - A cylindrical coil acting on a movable electro-magnetic core or plunger in the center of the coil.

**Solid-state** - Solid-state devices perform their function without using moving parts. Capacitors, diodes, SCR's, etc. have no moving parts but can perform certain functions depending on their condition. The opposite of solid-state are devices such as relays and switches, which require mechanical motion to perform their function.

**SPDT switch** - A single-pole, double throw switch.

**SPST switch** - A single-pole, single throw switch.

**Stability** - The ability to maintain or quickly reestablish a steady-state condition after a load change.

**Star connection** - See Y connection.

**Starting current** - The initial value of current drawn by a motor when it is started from standstill and when full line voltage is applied across its terminals.

**Stator** - The stationary part of a generator.

**Stator winding** - The armature winding, located in the stator core of a revolving field generator, in which the output voltage is induced.

**Surge** - A sudden transient variation in current, voltage or frequency.

**Surge suppressor** - A device capable of conducting high transient voltage, which protects other devices that could be destroyed.

**Synchronism** - The state of being of the same frequency and in phase.

**Synchronizing** - To match one wave to another, by adjusting its frequency and phase angle until they coincide.

**Synchronous** - Applied to a type of motor or generator in which the relation between frequency in hz per second and the speed in rpm is fixed and invariable.

**Tachometer** - A device for measuring rpm.

**Tap** - A connection point in the body of a coil or resistor.

**Telephone influence factor** - higher harmonics in the wave form of generator transmission lines which can cause undesirable effects on telephone or radio communications.

**Temperature drift** - A condition in which temperature changes cause a regulated value to deviate from the nominal value.

**Terminal** - A fitting for convenience in making electrical connections.

**Three wire system** - An ungrounded three phase AC generator output system.

**Time delay relay** - A relay which opens or closes its contacts after a certain time interval has elapsed since its actuating impulse is received by the coil. Generally, the interval is adjustable.

**Transformer** - A device which changes the voltage of an AC source from one value to another.

**Transient** - A temporary change in steady-state conditions occurring during load changes.

**Transistor** - An active semi conductor having three or more terminals.

**Unity power factor** - A load whose power factor is 1.0 or 100%. This is the case when no inductive loads (motors, transformers, etc.) are present and only resistive loads, (incandescent lights, furnaces, etc.) are connected.

**V** - Volt.

**VA or volt ampere** - The product of volts times amperes. Used to designate the rating of a transformer or generator.

**VAR or reactive volt ampere** - see reactive KVA.

**Volt** - Unit of electrical potential.

**Voltage** - The electrical potential or pressure which causes current to flow in a conductor.

**Voltage dip** - The momentary reduction in voltage resulting from an increase in load.

**Voltage droop** - Decrease in steady-state voltage of a generator caused by increase in load from no load to full load without change in voltage regulator adjustment. This decrease in voltage is expressed as a percent of full load voltage or:

$$\frac{\text{no load voltage (NLV) - full load voltage (FLV) x 100}}{\text{full load voltage}}$$

**Voltage droop compensation** - See definition same as CCCT before correction with addition of transformer or resistor.

**Voltage drop** - See IR voltage drop.

**Voltage regulation** - A measure of the degree to which a power source maintains its output voltage stability under varying load conditions.

**Voltage regulator** - A device which maintains the voltage output of a generator near its nominal value, regardless of load conditions.

**Voltmeter** - An instrument for measuring voltage.

**W** - Watt.

**Watt** - Unit of electrical power.

**Watt-hour** - unit of electrical energy equal to one watt of power consumed for one hour.

**Wattless power** - See reactive KVA.

**Waveform** - The shape of a wave, graphically represented.

**Wiring harness** - A pre-assembled group of wires of the correct length and arrangement to facilitate inter-connections.

**X** - reactance. Expressed in ohms.

**Y-connection** - Same as star connection. A method of interconnecting the phases of a three-phase system to form a configuration resembling the letter Y. A fourth or neutral wire can be connected to the center point.

**Z** - Impedance.

# Basic Marine Related Terminology

## HULL COMPONENTS

**Aft** - Toward, at or near the stern (back end), of vessel.

**Below** - Corresponding to "downstairs."

**Bilge** - The rounded portion of a vessel's shell which connects the bottom with the sides.

**Bow** - The forward end of a vessel.

**Bulkhead** - A vertical wall which divides the interior into compartments.

**Chine** - The edge formed between the side and bottom of a vee bottomed or flat bottomed vessel.

**Deck** - The part of a vessel corresponding to the floor of a building.

**Dry dock** - Holding area where sea going vessels are "pulled" for repair and supported in a dry area to facilitate work on all a parts of the vessel.

**Engine Bed** - Foundation on which the engine rests and is secured.

**Engine Stringers** - Longitudinal structural members which strengthen or support the engine bed.

**Forward or Fore** - Toward the bow or stern.

**Freeboard** - The vertical distance from the deck line to the water line.

**Hull** - The body of a vessel including framework, planking, decking, and bulkheads.

**Inboard** - Inside of a vessel; toward the longitudinal centerline of the hull.

**Iso** - International Standards of Units. Covers rules for use of the SI system.

**Keel** - The "backbone" of a ship. A structural member running longitudinally on the bottom of the centerline of the vessel.

**Kort nozzle or Ducted Propeller** - A venturi-like shell fitted around a propeller to increase efficiency under heavy towing conditions. i.e.: Tugs, Draggers, Trawlers & Push-boats.

**Mid-ship** - At or near the mid-point of a vessel's length.

**On board** - On or in the vessel.

**Port** - An opening in the side of a vessel. The left-handed side of a vessel looking from the stern.

**Rudder** - A swinging vane hung to the stern post by which the vessel is steered.

**Sea Cock** - Valve admitting sea (raw) water into vessel.

## PROPULSION TERMINOLOGY

**Blade Area** - The surface of propeller blade which act against the water (measured in square inches).

**Blade Pressure** - The pressure (in psi), upon the blade area of a propeller.

$$\text{Blade Pressure} = \frac{\text{Thrust (lbs.)}}{\text{Blade area (sq. in.)}}$$

**Diameter** - The outside diameter of the propeller in inches, taken at the tips of the propeller blades. Twice the distance from the shaft center to the tip of a blade.

**Pitch** - The linear dimension, in inches, of the advance of the propeller in one revolution at zero slip.

**Pitch Ratio (P/d)** - The ratio of propeller pitch to the diameter.

**Propeller Face** - The FACE of the propeller blade is its after or pressure surface.

**Propeller Back** - The BACK of the blade is the forward or curved "suction" surface.

**Propeller Rotation** - A right hand propeller turns clockwise when looking at the stern of a boat looking forward.

A left hand propeller turns counter-clockwise when looking at its face.

Outboard turning propellers are those whose blade tips above the shaft turn outboard in when moving forward.

Inboard turning propellers are those whose blade tips above the shaft turn inboard in when moving forward.

**Slip** - The "apparent slip" is the difference between the theoretical speed which the vessel would obtain if the propeller were turning in a solid medium (zero slip), and the actual speed of the vessel over a measured distance.

$$\text{Apparent slip} = \frac{\text{(Pitch x rpm) - (Speed of boat x 101.33)}}{\text{Pitch x rpm (using Pitch in terms of feet and speed in knots)}}$$

**Strut** - A support for the propeller shaft under the stern of the boat.

**Tailshaft** - The aft section of a propeller shaft which receives the propeller.

**Thrust, Propeller** - Pressure on the propeller shaft which receives the propeller.

**Twin Screw** - A vessel equipped with two propellers arranged one on the port side and one on the starboard side of the keel.

## MISCELLANEOUS TERMS & FORMULAS

**Coefficient, Block (Cb)** - The ratio which the underbody of the hull occupies within a rectangular block having a length equal to the waterline length of the hull, a width equal to the waterline beam and a depth equal to the molded draft.

$$Cb = \frac{D \times 35}{L \times B \times d}$$

**Displacement** - $D = \frac{L \times B \times d \times Cb}{35^* \text{ or } 36^*}$

Where: L....Wateline length.

B....Waterline beam.

d....Molded draft.

Cb.... .80 - .90 for self propelled barge.

.70 - .80 for river towboats.

.50 - .70 for blunt cargo boats and tugs.

.35 - .45 for pleasure boats.

*35... Cubic feet of sea water required to make a long ton

**36..Cubic feet of fresh water required to make a long ton

**Knot** - A unit of speed equivalent to one nautical mile per hour or 1.152 statute miles per hour.

**Mile** - Statute - 5,280 feet.

Nautical - 6,076 feet. (1.152 statute miles)

**Speed - Beam Ratio** - A convenient ratio used for comparing capabilities of hulls, particularly planing hulls.

**Speed - Length Ratio (S/L)** - Ratio of a vessels speed in knots divided by the square root of its waterline length in feet. A convenient ratio used for comparing the wave making characteristics of displacement hulls. Normal S/L ratio for displacement hulls is 1.34.

$$S/L = \frac{\text{Speed}}{\text{Length}}$$

**Ton** - A measure of weight or volume:
Long ton = 2240 lbs.
Short ton = 2000 lbs.
Metric ton = 1000 kg = 2204.6 lbs.
Register ton = 100 cubic feet.

**Water, weight** - Sea water = 64 lbs. per cubic foot.
= 35 cu. ft. per long ton.
Fresh water = 62.4 lbs. per cubic foot.
= 36 cu. ft. per long ton.

**Waterplane Area** - The area of the surface of the vessel bottom in contact with the water.

**Waterplane Coefficient** - The ratio of a vessel's waterplane area to the product of its length and beam.

# Industrial Terminology

**Aeration** - The entrainment of gas (air or combustion gas) in the coolant.

**Aftercooled** - Process by which the compressed combustion air from the final turbocharger on the intake side is pre-cooled before introduction into the air intake manifold (also referred to as intercooled).

**Air Bleed** - Pressurized air extracted from the gas turbine engine.

**Air Cleaner** - Device to filter combustion air, prior to entering the engine.

**Air Cooled Engine** - An engine that is cooled by means of air being forced about the heated parts of the engine.

**Air Intake Silencer** - Device to muffle sound of incoming combustion air and objectionable noise originating in the intake manifold.

**Air Restrictor Indicator** - A device applied in conjunction with a dry-type air cleaner to determine the maintenance interval of the filter cartridge.

**Air Starting** - Utilizes compressed air for engine or turbine starting.

**Altitude** - The vertical elevation relative to sea level at which the generating system is operating.

**Altitude Rating** - The power recommended by the manufacturer for satisfactory operation at a given altitude.

**Ambient Temperature** - The environmental air temperature in which the prime mover is operating.

**Angle of Operation** - The maximum deviation from horizontal at which an engine operates in a given application.

**Auxiliary Fuel Pump** - A pump separate from the prime mover that is usually used where main fuel storage is some distance from the engine driven fuel pump.

**Back Pressure** - Exhaust system pressure resulting from restricted exhaust gas flow.

**Base Mounted Fuel Tank** - Fuel tank that is incorporated into the generating system subbase.

**Battery Warmer** - Heater used in extreme cold climate to insure battery electrolyte solution does not freeze.

**Block Heater** - Heater device located in the cylinder block water jacket to warm engine coolant.

**Blower Fan** - A fan positioned in a cooling system such as the air passes through the fan before entering the radiator.

**Brake Horsepower** - The power available at the flywheel, or other output member(s) for doing useful work.

**Brake Mean Effective Pressure (B.M.E.P.) -** Theoretically, the average pressure which needs to be exerted during the engines power stroke to produce a power output equal to the brake horsepower.

**Brake Power** - Power available at the output member(s) for doing useful work.

**Bypass Oil Filter** - See Partial Flow Filter

**City Water Cooling** - Cooling derived from public utility water.

**Clogging Indicator** - An indicator which is activated when a predetermined pressure differential across the filter is reached.

**Closed Cycle Gas Turbine Engine** - A closed cycle engine which has working fluid independent of the atmosphere.

**Combination Medium** - A filter medium composed of two or more types, grades or arrangements of filter media to provide properties which are not available in a single filter medium.

**Combustion Air** - The air that enters the engine and is mixed with the fuel for the combustion process.

**Combustion Chamber** - See Combustor

**Combustor** - That portion of an engine in which fuel is burned.

**Compression Ignition** - Utilizes the heat caused by compression to initiate the combustion process.

**Compression Ratio** = $\frac{\text{Maximum Cylinder Volume}}{\text{Minimum Cylinder Volume}}$

**Continuous Brake Power** - Power recommended by the manufacturer for satisfactory operation under the manufacturer's specified continuous duty conditions.

**Coolant** - A fluid used to transport heat from one point to another.

**Coolant Heater** - A device used to heat the engine coolant at cold ambient temperatures.

**Cooling Air** - The air that is used to cool the unit.

**Cooling System** - A group of interrelated components to effect the transfer of heat.

**Cooling System Capacity** - The amount of coolant designated by the manufacturer to completely fill the cooling system.

**Corrected Power** - Observed power adjusted to standard atmospheric conditions.

**Critical Silencer** - An exhaust silencer that is applied in sensitive noise control areas.

**Day Tank** - A small fuel tank usually adjacent to or in close proximity to the engines driven fuel pump which stores a ready fuel supply near the engine.

**De-aerating Tank** - A tank capable of removing entrained air and/or combustion gas from circulating coolant.

**Delivered Air-Fuel Ratio** = $\frac{\text{Mass of Delivered Air}}{\text{Mass of Delivered Fuel}}$

**Differential Pressure Indicator** - A device which indicates continuously during operation the differential pressure across a filter element.

**Displacement** - The swept volume of a cylinder.

**Disposable Element** - A filter which is discarded and replaced at the end of its service life.

**Disposable Filter** - A filter consisting of a filter element encased in a house which is discarded and replaced in its entirety at the end of the service life of the element.

**Droop-Engine Speed** - The difference between the speed of the engine, when rated load is applied, and the speed of the engine running at no load, with a fixed governor setting.

**Dual Porosity Element** - An element which contains two media of different porosity in parallel.

**Dual Porosity Filter** - A filter which contains two media of different porosity offering parallel flow paths to the fluid.

**Dual Rate Charger** - Refers to an automatic battery charger that is capable of maintaining starting batteries at a reduced rate and then switching to a high charge rate to rapidly recharge discharged batteries.

**Duplex Fuel Filter** - A second filter in addition to the primary filter. Sometimes understood to mean a switchable system. For example, the filter is switched while the engines is running, the original filter replaced without interfering with normal running operation.

**Effective Area** - The area of a filter medium through which fluid flows.

**Electrical Starting System** - Utilizes electrical energy (battery) through a motor.

**Element Pressure Differential** - See Filter Pressure Differential

**Engine Charge Air Cooler** - A heat exchanger used to cool the charge air of an internal combustion engine after it has been compressed by an exhaust driven turbocharger and/or mechanically driven blower. Engine charge air coolers are often referred to as either intercoolers or aftercoolers depending upon their location, relative to the final compression stage, in the air induction system.

**Engine Displacement** - The swept volume of a piston, in one stroke times the number of engine cylinders.

**Engine Driven Battery Charger** - Battery charging alternator, or generator driven by the engine.

**Engine Rating** - The value of engine power output assigned by the manufacturer, to indicate the maximum power level at which the engine should be applied in a given application.

**Engine Safety Controls** - Devices that protect against catastrophic damage by shutting the engine down in the event of high coolant temperature, low lube oil pressure, low coolant level, or overspeed.

**Engine Speed** - The rotating velocity of the engine flywheel, measured in revolutions per minute.

**Equalizing Timer** - Used in conjunction with automatic battery charger to insure all cells are charged.

**Excess Fuel Device** - Any device provided for giving an increased fuel setting for starting only, generally designed to automatically restore action of the normal full load stop after starting.

**Exducer** - The fluid exit portion of a radial turbine wheel.

**Exhaust system** - The exhaust system changes the products of combustion (exhaust gases) from the engine into the atmosphere at the desired location.

**Fan Air Flow** - The rate of air flow usually in units of cubic feet (cubic meters) per minute that a fan can deliver at standard air conditions, and a specified static pressure and speed.

**Filter** - A device having a porous medium, whose primary function is the separation and retention of particulate contaminants from a fluid.

**Filter Capacity for Contaminants** - The weight of specified contaminant removed and held from the fluid by a filter at a specified termination point.

The termination point is specified as a pressure differential, reduction in flow, filtration efficiency, or fluid contamination level.

**Filter Efficiency** - The ability, expressed as percent, of a filter to remove specified artificial contaminant from a specified fluid under specified test conditions.

**Filter Element** - A sub-assembly of a filter which contains the filter medium or media.

**Filter Housing** - A ported enclosure which contains the filter element and directs fluid flow.

**Filter Medium** - The porous material which performs the process of particle separation and retention.

**Filter Pressure Differential** - The drop in pressure due to flow across a filter or element at any time. The term may be qualified by adding one of the words "initial," "final," or "mean."

**Filter Rated Flow** - The maximum flow rate of a fluid of specified viscosity for which a filter is designed.

**Final Filter** - The last stage of a multi-stage filter system.

**Flexible Exhaust Connection** - Flexible section between the exhaust manifold and exhaust line (pipe).

**Flexible Fuel Lines** - Pliant coupler line used between engine and supply lines.

**Float Charger** - Automatic battery charger that continually monitors battery voltage and adds charge automatically at preset level.

**Flow Rate, Coolant** - The rate of flow of coolant through a cooling system component or group of components under specified conditions in gallons (liters) per minute.

**Four Cycle Engine** - Utilizes four strokes to complete a power cycle.

**Frequency Droop** - The change in frequency (hertz) from steady state full load to steady state no load.

**Fuel Heaters** - A device used to heat fuel at cold ambient temperatures.

**Fuel Injection Tubing** - The tube connecting the injection pump to the nozzle holder assembly.

**Fuel Injector** - An assembly which receives a charge of fuel from another source at a relatively low pressure, then is actuated by an engine mechanism to inject the charge of fuel to the combustion chamber at high pressure and at the proper time.

**Fuel Lines** - Tubes used to convey fuel to the engine.

**Fuel Storage Tank** - A container used to store the fuel used by the prime mover.

**Fuel Strainer** - A course wire mesh strainer usually used in conjunction with gas lines and heavy fuels.

**Fuel Transfer Pump** - The integrally mounted and driven pump on the engine which supplies fuel to the operating system.

**Full Flow Oil Filter** - A filter through which all of the system's oil flows.

**Full Load Stop** - A device which limits the maximum amount of fuel injected into the engine cylinders at the rated load and speed specified by the engine manufacturer.

**Fully Equipped Engine** - An engine equipped with all the accessories necessary to perform its intended functions unaided. This includes, but is not restricted to, intake air system, exhaust system, cooling system, generator or alternator, starter, and emission control equipment.

**Gasifier** - That part of the engine that supplies heated, pressurized gas to the power turbine. Typically the compressor/turbine/combustor section of a two shaft-free power turbine engine.

**Gas Generator** - See Gasifier

**Gas Producer** - See Gasifier

**Gas Turbine Engine** - A rotary prime mover which uses an essentially continuous process to compress, heat, and expand a gaseous working fluid.

**Governor** - A device used to control the prime mover speed.

**Governor Regulation** - The difference between the steady state engine speed at rated load and the steady state engine speed at no load, expressed as a percentage of the rated load speed.

**Gross Power** - Power output of a "basic" engine.

**Heat Exchanger Cooling** - Engine coolant heat is dissipated to water through a liquid to liquid heat exchanger.

**Heavy Duty Air Cleaner** - An engine air cleaner with greater dust holding capacity for applications where operations will be in heavy dust concentration for sustained periods.

**Horsepower** - A measure of engine power output equivalent to 550 FT-LB/Second.

**Hydraulic Governor** - Achieves prime mover speed control by balancing a hydraulic force against a spring force.

**Hydraulic Starting System** - Starting system that utilizes pressurized hydraulic oil through a motor for starting.

**Industrial Silencer** - An exhaust muffler used to produce the silencing level normally associated within industrial areas.

**Injection Pump** - The device which meters the fuel and delivers it under pressure to the nozzle and holder assembly.

**Intercooler** - A heat exchanger that reduces the temperature of combustion air before initial compression; also referred to as aftercooler.

**Intermittent Brake Power** - Highest power recommended by the manufacturer for satisfactory operation within the manufacturer's specified conditions of load, speed, and duty cycle.

**Isochronous Governor** - A governor that maintains a constant engine speed from no load to full load.

**Keel Cooling** - Used in marine applications to dissipate engine coolant heat to the sea through a keel mounted heat exchanger.

**Liquid Cooled Engine** - An engine that is cooled by means of liquid coolant circulated about the heated parts of the engine. The coolant is then passed through a radiator or heat exchanger where it is cooled and then re-circulated to the engine.

**Load Factor** - The ratio of the average load imposed on the prime mover to the prime mover rating.

**Load-Sensing Governor** - An engine speed control device for use on engine generator sets to anticipate engine fuel setting changes as a function of changes in electrical load.

**Lube Oil Heater** - A device used to heat the engine lube oil at cold ambient temperatures.

**Maximum Brake Power** - Highest power developed at a given speed.

**Mechanical Governor** - Achieves prime mover speed control by balancing the force exerted by rotating flyweights against a spring force.

**Naturally Aspirated** - Engine combustion air flow is not assisted by artificial means such as a supercharger or turbocharger.

**Net Power** - Power output of a "fully equipped" engine.

**Normal Duty Air Cleaner** - Applications where there is a relatively light concentration of dust.

**Nozzle** - The assembly of parts employed to atomize and deliver fuel to the engine.

**Nozzle and Holder Assembly** - The complete apparatus which injects the pressurized fuel into the combustion chamber.

**Observed Power** - Power actually developed by an engine under the atmospheric conditions existing during the test.

**Oil Immersion Heater** - Device used to heat the engine lubricating oil.

**Open Cycle Gas Turbine Engine** - A gas turbine engine in which the working fluid enters the engine from the atmosphere and discharged to the atmosphere.

**Overheating** - An operation condition where coolant temperature exceeds design intent. This may be caused by deficiency in the cooling system or by abnormal operation conditions.

**Overspeed Governor** - A mechanical speeds-sensitive device that through mechanical or electrical action (operation of a switch) acts to shut down the engine and limit the speed by cutting off fuel and or air supply should the engine speed exceed a preset maximum.

**Parasitic Load** - The extra load caused by the engine driven accessories such as the cooling system fan and battery-charging alternator.

**Partial Flow Filter** - A filter which filters only a part of a total system fluid.

**Peak Shaving** - Process by which utility customer minimizes utility charges by either generating power and eliminating excessive demand charges or by shedding load.

**Piston Speed** - The piston speed of an engine is the total feet of travel made by each piston in one minute. Formula is: Piston Speed = Stroke in feet x rpm x 2

**Pre-Alarms** - Warning prior to actually actuating the automatic engine safeties to indicated impending shutdown.

**Pre-Cooler** - A heat exchanger that reduces the temperature of the working fluid before initial compression.

**Pre-Lube** - An auxiliary to the standard lube oil pump which provides lubrication to the engine prior to starting.

**Pressure Reducing Valve (Gas)** - Valve used to reduce gas line pressure to usable limits of the gas carburetor.

**Pressure Reducing Valve (Water)** - Valve used to reduce water pressure between the main and the engine-cooling system

**Primary Filter** - The first stage of a multi-stage filter system.

**Pyrometer** - An instrument used to measure exhaust gas temperatures.

**Radiator** - A heat exchanger that is used to transfer engine coolant heat to the atmosphere.

**Radiator Cooling** - Engine coolant heat is dissipated to the atmosphere through a radiator.

**Rated Power** - Power specified by the manufacturer for a given application at a given (rated) speed.

**Raw Water Cooling** - See City Water Cooling

**Recuperator** - A heat exchanger in which energy is transmitted from a flowing hot fluid to a flowing cold fluid through a wall whose function is to separate the two fluids.

**Reheat** - Combustion subsequent to expansion.

**Regenerative Cycle Gas Turbine Engine** - A gas turbine engine employing exhaust heat recovery in the thermodynamic cycle consisting of successive compression, regenerative heating, combustion, expansion, and regenerative cooling (heat transferred to compressor discharge air) or the working fluid.

**Regenerator** - A heat exchanger in which energy is transmitted from a flowing hot fluid to a flowing cold fluid by alternately passing these fluids through the same mass of material.

**Remote Radiator** - Radiator and fan that is not mounted to, or driven by the unit.

**Residential Silencer** - An exhaust muffler used to produce the silencing level usually associated with residential areas.

**Secondary Filter** - The second stage of a multi-stage filter system.

**Single Shaft Turbine Engine** - A gas turbine engine in which the compressor and turbine are mechanically coupled to the same shaft, and mechanically connected to the power output shaft either directly or though gearing.

**Skin Enclosure** - Weatherproof enclosure that is minimal and usual follows contour of equipment being protected.

**Sound Attenuation** - Reduction of objectionable noise to acceptable limits.

**Spark Arrestor** - A device used to prevent sparks from being released with exhaust gases.

**Specific Fuel Consumption** - The amount of fuel consumed to produce a unit of work, usually expressed in pounds per horsepower or kilowatt hours, or grams per kilowatt hour.

**Specific Heat Rejection** - The heat rejection of the engine expressed essentially in British thermal units per minute per brake horsepower.

**Spin-on Filter** - A disposable filter which mates to a permanent base and is attached by turning onto a threaded base stud.

**Standby Service** - Generating equipment exclusively utilized in the event of failure of the utility supplied service.

**Starting System** - A group of components that is used to initially rotate the prime mover at a sufficient speed to get it started.

**Suction Fan** - A fan positioned in a cooling system so that air passes through the radiator before entering the fan.

**Supercharged Gas Turbine Engine** - A gas turbine engine containing two mechanically independent rotors, each containing a driving turbine; one compressor operating with an air inlet at atmospheric pressure, which supercharges the second compressor inlet to a higher pressure. Useful power may be taken from either of the rotors, or from a free power turbine.

**Supply Pump** - A pump for transferring the fuel from the tank and delivering it to the injection pump.

**Surge Tank** - A separate tank in the cooling system provided to perform one or more of the following functions; (1) filling, (2) coolant reservoir, (3) de-aeration, (4) retention of coolant expelled from radiator by expansion and/or after boil, and (5) visible fluid level indication.

**System Air Flow Restriction** - The static pressure differential which occurs at a given air flow from air entrance through air exit in a system, generally measured in inches (millimeters) of water.

**Thermo-Regulating Valve** - Heat actuated valve that limits amount of city or raw cooling water into the system to conserve water and regulate cooling.

**Thermostat** - A device that is heat actuated to maintain the circulating water temperature at a pre-determined level.

**Timing Device** - A device responsive to engine speed and/or load to control the timed relationship between injection cycle and engine cycle.

**Torque** - Force required to move a shaft around its axis, measured in foot pounds.

**Torsional Analysis** - A twisting vibration which occurs in rotating machinery that contains two or more masses having significant moments in inertia interconnected by shafting having significant elasticity.

**Total Energy** - Refers to process whereby independent user generates on-site power and utilizes exhaust heat, and jacket water heat in addition to electricity generated.

**Turbine** - That component of the engine which produces torque from expansion of the working fluid. Consists usually of turbine nozzle and a turbine wheel which together constitute a turbine stage. A multi-stage turbine comprises more than one turbine stage.

**Turbine Nozzle** - An arrangement of stationary blades for directing the flow of gas into a turbine wheel.

**Turbine Wheel** - The rotary component of the turbine stage which consists of a series of blades or buckets through which the fluid flows. May be an axial, radial, or mixed flow type.

**Turbocharger** - A centrifugal air pump driven by engine exhaust gases and used to supply engine charge air at flows and pressures above atmospheric.

**Two Cycle Engine** - An internal combustion engine utilizing two strokes to complete the power cycle.

**Two-Shaft Free Power Turbine Engine** - A gas turbine engine in which the compressor and its driving turbine are mounted on one shaft and the output power turbine is mounted on a separate shaft supplying useful power.

**Two Spool Engine** - See Supercharged Gas Turbine Engine

**Two Stage Element** - A filter element assembly composed of two filter media in series.

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