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STUDENT HANDOUT

MOTORS

1. OVERVIEW: The purpose of this lesson is to provide you with the basic knowledge of motors and motor controls.

2. LEARNING OBJECTIVE(S):

a. TERMINAL LEARNING OBJECTIVE(S):

(1) Provided a motors trainer, multimeter and a malfunctioning motor, repair the motor so the it runs properly, in accordance with Electric Motor Repair. (1142.01.06)

(2) Provided a motors trainer, multimeter and a malfunctioning motor control, repair the motor control, in accordance with Industrial Motor Controls. (1142.01.07)

b. Enabling Learning Objective(S):

(1) Given a list of electric motor components, and a list of electric motor component functions, match each component to it's function in accordance with Electric Motor Repair. (1142.01.06a)

(2) Given a list of electric motors and a list of electric motor descriptions, match each motor to it's description in accordance with Electric Motor Repair. (1142.01.06b)

(3) Provided a motor trainer, a multimeter, and a single phase motor, wire the motor so that it runs properly, in accordance with Electric Motor Repair. (1142.01.06c)

(4) Provided a motor trainer, a multimeter, and a three phase motor, wire the motor so that it runs properly, in accordance with Electric Motor Repair. (1142.01.06d)

(5) Provided a motors trainer, a multimeter, and a single phase motor wired to run in reverse, rewire the motor so that it runs properly, in accordance with Electric Motor Repair. (1142.01.06e)

(6) Provided a motors trainer, a multimeter, and a three phase motor wired to run in reverse, rewire the motor so that it runs properly, in accordance with Electric Motor Repair. (1142.01.06f)

(7) Provided a motors trainer with fault plugs installed, a multimeter, and a split phase motor, identify the fault, in accordance with Electric Motor repair. (1142.01.06g)

(8) Provided a motors trainer with fault plugs installed, a multimeter, and a capacitor start motor, identify the fault, in accordance with Electric Motor Repair. (1142.01.06h)

(9) Provided a motors trainer with fault plugs installed, a multimeter, and a three phase motor, identify the fault, in accordance with Electric Motor Repair. (1142.01.06i)

(10) Given a list of motor controls and a list of motor control functions, match each motor control to its function, in accordance with Industrial Motor Controls. (1142.01.07a)

(11) Given a list of motor control components, and a list of motor control components functions, match each motor control component to its function, in accordance with Industrial Motor Controls. (1142.01.07b)

(12) Provided a malfunctioning motor control, a motors trainer, and a multimeter, identify the malfunction, in accordance with Industrial Motor Controls. (1142.01.07c)

(13) Provided a malfunctioning motor control, a motors trainer, and a multimeter, repair the malfunction, in accordance with Industrial Motor Controls. (1142.01.07d)

<u>OUTLINE</u>

1. <u>ELECTRIC MOTOR COMPONENTS</u>:

a. <u>The stator</u> is one of the main parts of the electric motor. The stator is made up of thin sections of soft iron or steel, called laminations. The stator is an electric magnet. Here the south and north magnetic poles are created. The soft iron laminations act as the core of this electric magnet. Insulated wire is wound around the laminations. When the AC is applied to these windings the magnetic poles change and reverse from south to north, then from north to south. This changing polarity occurs 120 times per second. This is due to the constant changing of alternating current. A full value of each magnetic pole occurs during each alternation. There are two alternations per cycle and the standard electrical frequency of alternating current in the United States is 60 Hz. Therefore, each second the poles change polarity, 120 times.

b. <u>The rotor</u> is the second main part of the motor. The rotor is the part of the motor that spins. There are two main types of rotors:

(1) <u>Squirrel cage rotors</u> are found in induction motors. They have metal bars that are assembled similar to that of a wheel used to exercise hamsters or caged squirrels. Round disks of thin metal are

stacked and serve as the core for this rotor for when it operates as an electro magnet.

(a) The squirrel cage rotor receives electrical energy from the stator. In an induction motor there are no electrical connections from the stator to the rotor. Electrical energy is passed from the stator to the rotor by way of electromagnetic induction. The stator acts like a primary winding of a transformer, and the rotor acts like the secondary winding. The three things needed to produce electricity in the rotor are present.

1 First we can view the relative motion that occurs from the alternating current in the stator.

a During each alternation the magnetic field expands from the stator and cuts through the rotor and continues to move until the alternation reaches peak voltage (EP). At this point the magnetic field has expanded to its full values.

b When the alternation decreases, so does the magnetic field. This causes the magnetic field to collapse. As the magnetic field collapses and withdraws back through the rotor, this is also considered motion.

2 The second thing needed to produce a voltage using magnetism is a magnetic field. We have already described the magnetic field that is being produced by the stator windings.

3 The third thing needed to produce a voltage using magnetism is a loop conductor or closed loop circuit. The squirrel cage rotor will provide a complete circuit due to the metal bars that are all brought together in an electrical circuit with one another. This is accomplished by the rings that electrically and physically connect the metal bars at both ends of the rotor.

a Current starts to flow through the rotor bars.

b Since all current carrying conductors have a magnetic field surrounding them, the rotor creates its own magnetic field.

(b) The magnetic fields of the stator repels and attracts the rotor and through the laws of magnetism, (likes poles repel and unlike poles attract), the rotor spins.

(2) The second type is the armature rotor. Unlike the squirrel cage, it is wire wound.

(a) Windings are formed using insulated wire (wire coated with a varnish).

(b) The connection to these windings is made by the commutator, which is part of the armature.

1 The commutator consists of copper segments separated by an insulating material called mica. These segments, attached to conductors in the rotor, provide electrical connections to the windings.

2 The commutator receives electrical energy via a set of brushes that ride on the commutator.

a Brushes are made of soft carbon and are conductive.

b Brushes are held in place by brush holders.

c Brush springs are used to ensure that the required pressure is applied between the commutator and brushes. The springs take up any volume that may occur otherwise due to the brushes wearing down.

d The brushes may be supplied directly from an external power source such as a battery or they may be supplied from the stator by electrical connections.

e In some motors after starting, the brushes are lifted off the commutator by a centrifugal device and then a ring slips over the commutator shorting the segments; therefore, causing all the windings to be electrically the same. This is similar to the bars in the squirrel cage rotor; furthermore, this allows the armature to operate like that of a squirrel cage rotor by using electromagnetic induction.

3 the armature has a laminated core similar to the squirrel cage rotor.

c. The endbells or endshields - These provide support for either end of the rotor and bearings, or the brushes and slip rings, depending on the type of motor.

d. The cooling fan - Is attached to the rotor shaft within the endbells and stator, it is designed to draw air in through the motor to cool it.

e. Bearings - The bearings provide steady, even support for the rotor and allow the rotor to turn with minimum friction. There are two sets of bearings, one on each end of the rotor shaft. The bearings are sealed, usually the roller bearing type, with lubricating grease pressed together between two ring type retainers.

f. Centrifugal switch - Found in both split-phase and capacitor start motors. This switch is in series with the start windings and cause them to be taken out of the circuit once the motor has reached normal operating speed. Normally this switch is made having two assemblies:

(1) Mounted on the shaft is a mechanical device that is spring loaded and reacts to the centrifugal force caused by the spinning of the rotor.

(2) Mounted inside the motor is a set of contacts that move according to the position that the mechanical device is in. The mechanical device can cause the contacts to open, once the rotor has reached a certain speed.

(3) Once the motor is shut off and the rotor slows down, the mechanical device goes back to its original position because it is spring loaded; thus, the contacts close, bringing the start windings back into the circuit.

2. DESCRIPTIONS OF ELECTRIC MOTOR: There are three motors we will discuss during this class. We will cover two types of single phase motors (split-phase and capacitor start motor) and then we will discuss the three phase motor.

a. Single phase motors work off single phase power. The first motors that we will learn about work off 110 volts, single phase.

(1) Split Phase Motors are commonly found with Marine Corps equipment. It is the starting aid or method of starting in which a motor is named after. To understand the operation of a split phase motor it is necessary to follow the chain of events which occur through the starting and running of this motor.

(a) Single phase power first enters the stator through the power cord or conductors which supply the stator winding with electrical energy. The stator is made up of copper wire which is wrapped around soft iron. The iron laminations, we have already learned in our discussion of motor components, become magnetized. The stator is made up of two sets of windings in the split phase motor.

1 The start windings are higher resistance when compared to the other set of windings. They are made of thinner wire which causes them to be magnetized first.

2 The run windings are connected parallel with the start. They become magnetized after the start windings. The difference in timing between the magnetic field in the start and the magnetic field in the run cause a rotating magnetic field to be present in the stator. The speed of the rotating magnetic field is referred to as the synchronous speed.

(b) Both the start and run windings change their magnetic polarity from north to south with each alternation during a cycle. These magnetic poles having two alternations which we have discussed previously.

(2) The magnetic field from the stator expands and collapses through the rotor. As the magnetic field cuts through the rotor it induces current in the rotor; thus, current flows through the rotor.

This occurs through electromagnetic induction. The stator acts similar to that of the primary winding of a transformer. The rotor acts like the secondary winding of the transformer.

(a) The rotor sets up a magnetic field due to it being a current carrying conductor.

(b) Due to the laws of magnetism, the magnetic field from the stator influences the rotor to turn. This repulsion and attraction causes the rotor to spin, while a difference in timing occurs between the start winding and the run winding.

(c) When the rotor reaches 75% to 80% of the synchronous speed a centrifugal switch which is in series with the start winding opens the circuit taking the start winding out of the circuit. At this stage the run windings continue to operate changing magnetic poles from north to south 120 times a second:

b. The Capacitor start motor: Capacitor start motors are also found in Marine Corps Equipment. The motor is called a capacitor start motor for the obvious reason.

(1) As in the split phase motor single phase power enters the stator through the power cord. The stator of the capacitor start motor is similar to that of the split phase motor. It also has two sets of windings.

(a) The start windings in a capacitor start motor use a capacitor in series to change the timing between the magnetization of the start and the run windings. The effect a capacitor has on alternating current is that it opposes a change in voltage.

(b) The run windings are connected in parallel with the start windings as in the split phase motor. They have no capacitor since the capacitor is for starting purposes only.

(c) The start and run windings change their magnetic poles like the windings of a split phase motor, 120 times per second.

(2) The magnetic field from the stator induces current to flow through the rotor.

(a) The rotor, due to current flowing through it, sets up a magnetic field.

(b) The laws of magnetism cause the rotor to spin, while a difference in timing occurs between the start and run windings.

(c) When the rotor reaches 75% to 80% of the synchronous speed a centrifugal switch, that’s in series with the start windings, opens the circuit taking the start windings out of the circuit. The run windings continue to operate.

c. OPERATION OF THE THREE PHASE MOTOR: The three-phase or poly-phase motor physically resembles other motors we have covered; I.e.; all other motors have a stator and rotor.

(1) The stator windings are made up of three single phase windings. Each of these windings are physically spaced where they can best attract and repel the rotor using the laws of magnetism.

(2) The three phase motor requires three phase power. Each single phase winding receives electrical energy from one of the three phases. Each peak of three phase power occurs 120^0 from the next. We learned in our previous discussion that both the split phase and capacitor start motor had to achieve a difference in timing between windings. The magnetic field had to occur in a sequential order. Due to the three phase power having a difference in timing from peak to peak, it allows each phase to provide power to its own set of windings, a difference in timing is therefore achieved. The poles in each winding also change polarity from north to south 120 times a second. Each winding remains in the circuit during the starting and running operation. Each phase is equal in ohms.

(3) The rotor receives electrical energy through electromagnetic induction from the stator windings.

3. WIRING A SINGLE PHASE MOTOR: When wiring a single phase motor to a power source, follow the steps listed below:

a. The first step is to identify the type of motor and data that pertains to proper operation of the equipment. This information should be available on the motors data plate.

(1) The data plate is normally mounted on the side of the motor housing.

(2) Some equipment has a data plate on the equipment housing that contains the motor.

(3) Data plates often provide the following:

(a) Voltage

(b) Horse power (HP)

(c) Locked rotor amperage

(d) Type of motor, i.e. type “E” or “NONE”

b. The second step is to identify the motor leads that will be connected to the power source and know the basic rules for what is required to allow the single phase motor to operate as intended:

(1) There are at minimum two wires required to wire a single phase motor to a 110/120 volt system. However, grounding is an

important rule to follow. Ensure that the method of wiring provides a proper ground.

(2) Conductors are wired so that the motor windings are paralleled.

c. The third step is to identify the power source that will supply electrical energy to the motor.

(1) When connecting an electrical motor, an over-current protection devices is required. System/types of over-current protection may be:

(a) MEPDIS, the panels have circuit breakers built in for the protection of the loads connected to the system.

(b) Breaker boxes may be installed using the general illumination set or may be connected to an already existing system.

(c) Fuses may be used rather than breakers.

(2) The over-current protection should be sized by someone who is trained in the use of the National Electric Code.

(3) Test equipment should be used to test the voltages.

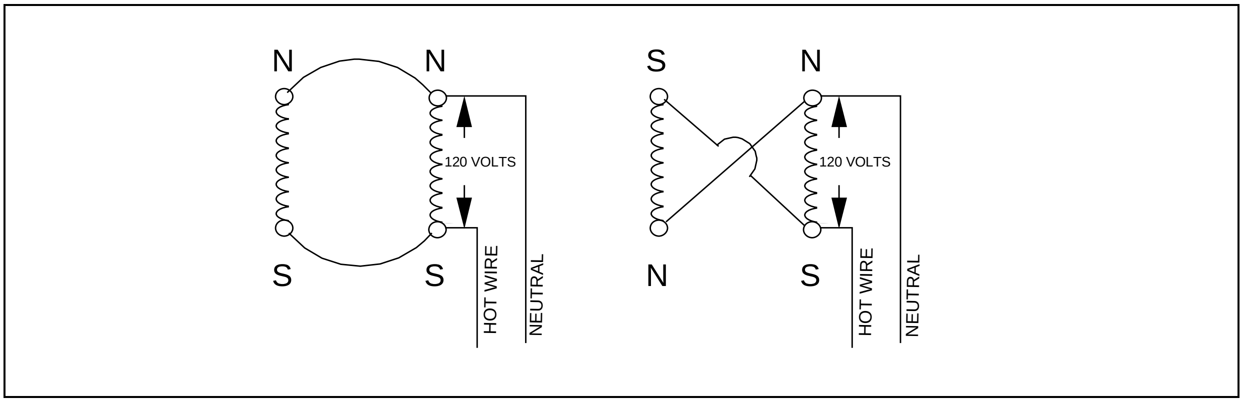
(a) When using generator load studs, LO and either L1, L2, or, L3 should provide 120 volts.

(b) When using commercial system any one hot wire and neutral should provide the required power of 110/120 volts. Always test voltages before connecting an electric motor to any system.

4. REVERSING THE DIRECTION OF A SINGLE PHASE MOTOR: The direction that any rotor spins, in both the single phase and three phase motor, depends on the sequence of the magnetic fields as they occur in the stator windings. The sequence of the magnetic fields in the single phase motor depend on the arrangement of the connections that cause the start and run windings to be in parallel.

(a) Both the start and run winding require a hot and neutral connected at each end.

(b) Reversing the connection of only one winding will change the sequence of the magnetic fields as they occur in the stator.



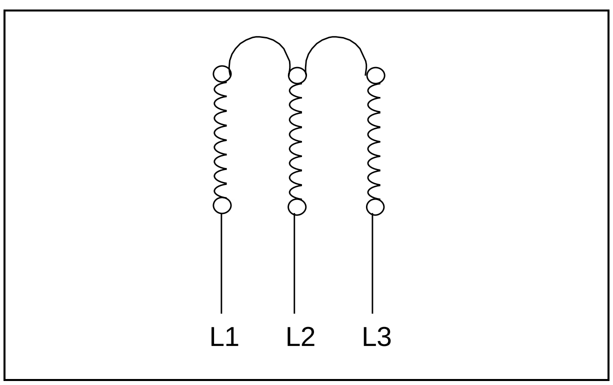
SINGLE PHASE MOTOR CONNECTIONS FOR FORWARD AND REVERSE
FIGURE 1

5. WIRING THE THREE PHASE MOTOR FOR OPERATION: When wiring the three phase motor the necessary steps for acquiring information are the same as the single phase motor.

(a) Confirm the information on the data plate.

(b) Identify the leads that come from the motor and connect them to the power source. A three phase motor requires a minimum of 3 conductors to operate. Like the single phase motor grounding is important.

(c) Test the power source for correct voltages. A reading should be taken across L1, L2, and L3. It is important to ensure each phase is providing the voltage. A three phase motor will turn with only two of the phases connected; however, this will most likely result in damage to the motor if this condition is allowed to exists for more then a brief time.



THREE PHASE MOTOR CONNECTIONS FOR OPERATION
FIGURE 2

(d) Once the three phase motor is connected observe the direction of rotation.

6. REVERSING THE DIRECTION OF A THREE PHASE MOTOR: The direction of rotation of a three phase motor as mentioned earlier depends on the

sequence of the magnetic fields as they occur in the stator windings. Unlike the split-phase motor and the capacitor start motor the sequence of how the magnetic fields occur depending on the sequence of the phases. Changing the direction of the three phase motor is less complicated than the single phase motor. Changing the direction of the three phase motor is accomplished by switching any two phases on the phase system.

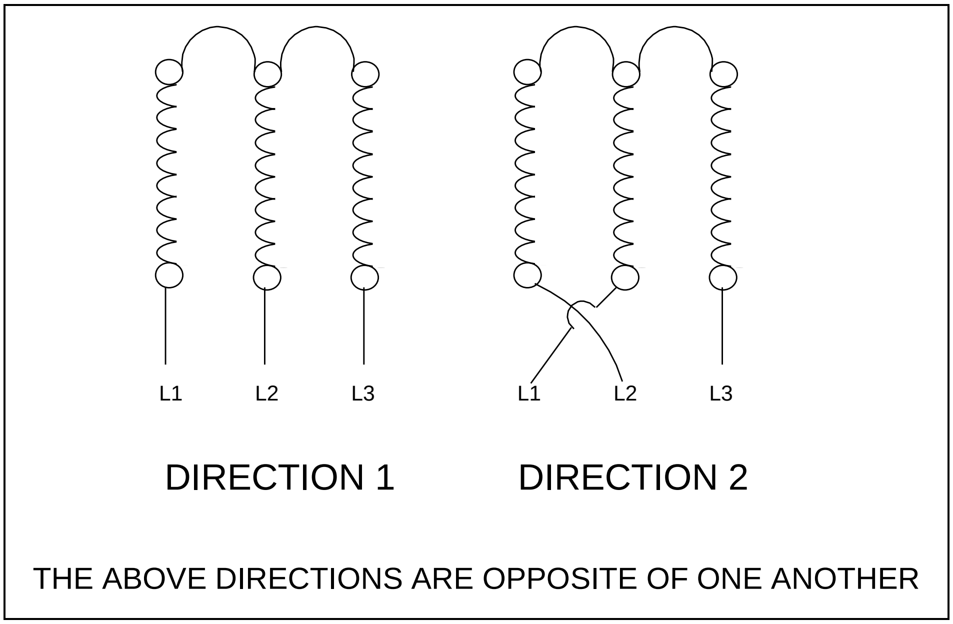


FIGURE 3 REVERSING THE DIRECTION OF THE THREE PHASE MOTOR BY SWITCHING ANY TWO PHASES.

7. <u>IDENTIFYING FAULTS IN A SPLIT PHASE MOTOR</u>: We have learned that the split phase motor has two sets of windings. To identify which windings are which, we use an ohm meter to measure the resistance. Using the 200 ohm scale compare the readings from the two sets of windings. The one with the higher resistance is the start windings. Obviously the windings with the lower resistance are the run windings.

a. When a winding has a short, it can be identified by a reading of 00.0 on the ohm meter. This low resistance reading indicates a fault. A short can occur in one winding or from winding to winding.

b. Another fault which may occur is called an open. An open is indicated when no continuity is found. The reading is the same when the leads are not connected to anything.

c. A fault which causes the motors to run backwards is called a reverse winding. This is due to one of the windings not being wound the same. Crossing over the conductors which parallel the windings would cause the motor to run in the proper direction.

8. <u>IDENTIFYING FAULTS IN A CAPACITOR START MOTOR</u>: When comparing the capacitor start motor to the split phase motor, they differ only when troubleshooting the start windings. We learned previously that the

start windings of a capacitor start motor has a capacitor in series. The 2k, or 2,000 ohm scale, is best for checking the start winding. When reading through the start winding the capacitor will cause the numbers to climb and drop back down to the original display on the meter. To view this again it is important to reverse the test leads on the terminals. This should be done on the first attempt, if when going across the terminals, no reading is obtained.

9. IDENTIFYING FAULTS IN A THREE PHASE MOTOR:

a. We learned previously that the three phase motor had three sets of windings. We also learned that the three windings are equal in ohmic value. The faults such as shorts and opens still appear to have the same reading as when checking a single phase motor. The reverse winding in a three phase motor however causes a different set of symptoms than that of the single phase motor.

(1) The motor makes a noise which is obviously different when compared to a properly operating three phase motor.

(2) The direction of the three phase motor is controlled by the sequence of phasing. However, a reverse winding will not affect the direction of a three phase motor.

(3) The three phase motor will draw extra current through the winding and may begin to smoke. If it continues to run with a reverse winding, damage will occur.

(4) The motor will run slower than its normal operating speed.

b. To correct a reverse winding, one winding must be reverse by switching the connection in which the phase is fed and the connection in which it is electrically connected to the other windings. Apply power and observe quickly to see if the fault has been corrected. If the fault is still present, put the connections back on the previous winding as they were and reverse one of the two remaining windings. If the fault has not cleared up then put the connections back as they were originally. This leaves one set of windings, reversing these connections should remove the fault.

10. MOTOR CONTROLS FUNCTIONS: Motor controls are devices that aid or allow motors to start or stop. This can be for a momentary operation, commonly referred to as a "jog", or for an automatic operation in equipment such as refrigerators, and washing machines with no operator present. Since, in essence, this device controls the motor, it is easy to see that if the motor control is not functioning properly it can easily cause malfunctions. Motor controls are classified in three basic categories.

a. Manual motor controls are in the first category we will discuss. These controls mainly consists of switches. There are many types of switches used in the application of controlling motors. The most common types are as follows:

(1) Single pole- single throw switch, "SPST". These switches are generally used for on-off applications, such as applying or removing source power to the motor. They come in toggle and knife blade style.

(2) Push button switches are a type of single pole-single throw switch. They are usually used to either make or break motor starting circuits. Push buttons come in two types.

(a) Normally open: Used to engage the starting circuit for starting the motor. Contacts are made by depressing the button.

(b) Normally closed: Used to de-energize power from the motor by depressing the button that opens the contacts.

(c) The term normally open or normally closed refers to the position of components contacts as they would appear in your hand with nothing else attached. For example, a switch on a refrigerator which causes the light to come on when you open the door, this is a normally closed switch. When you close the door it opens the contacts and the light goes off.

(d) Rotary switches: Generally used with variable speed and or reversible motors. Can be used to switch in different motor windings. Tapped transformers or chokes provide varied fixed voltages.

(e) Variac: Provides continuous variable voltages. It can be set at any desired position and operates off of a rotating contact that rides across the turns of a winding.

(f) Variable resistors: These come in various sizes and ratings. Two most common types are the potentiometer and the rheostat. They can be used to

<u>1</u> control line voltage

<u>2</u> limit current

<u>3</u> control speed

b. Automatic control devices are the second category of motor controls we will discuss. There is not enough time to cover all the automatic devices but we will discuss some of the most common controls for motors that you will see.

(1) Magnetic devices:

(a) Relays are magnetic devices that operate off electromagnetic coils which, when activated, cause a spring loaded arm to be influenced and moved toward the coil that is magnetized. This causes contacts to open or close.

1 Normally open relays: Contacts are open until the coil is magnetized, causing them to close.

2 Normally closed relays: Contacts are closed and are opened by the influence of the coil when it becomes magnetized.

(b) Relays used for starting motors such as in the hermetic compressor systems are usually either current relays or potential relays.

1 Current (magnetic) relay: A normally open relay, this relay's coil is connected in series with the run windings. The run winding consume more current when the rotor is not turning or turning at slow speeds than it does when the rotor reaches full speed. This high current flows into the run winding causing the relay coil to become magnetized. It closes the contacts which are connected to the start windings. As the rotor reaches speeds of two thirds to three fourths of its rated speed the ampere draw of the run windings decrease. This decreases the magnetic strength of the magnetic relay enough to allow the weight or spring to open the contacts and take the start windings out of the circuit.

2 Potential (voltage) relay: This is a normally closed relay and it is usually connected in series with the start windings. As the motor speed increases during starting, higher voltage in the start windings creates more magnetism in the relay coil pulling the contacts apart and opening the start circuit. The relay coil is made up of very small wire, allowing little current to flow through it, thus cutting down on the amount of heat.

c. The Cross Line Starter is a combination of manual/automatic.

(1) It is used in conjunction with a push button station.

(2) It uses a magnetic device called a holding coil similar to a relay to activate the motor.

(3) It has internal overload that provides some over current protection that shuts the motor off during abnormal conditions.

11. MOTOR CONTROL COMPONENTS

Before we can understand the function of a motor control, it is necessary to learn the symbols for the components. The crossline starter is a good example to learn motor controls from because it contains many components that other controls may have. For example, it has a holding coil, as does a relay. Likewise, both have contacts. I will point out each component symbol as it is connected in the circuit of the crossline starter, then explain the component.

a. The Push Button Station contains two type of switches:

(1) Normally closed push button is the stop button. One pole of this push button is connected to the connection labeled 7 and the other pole is connected to the connection labeled 1. While this switch is in the closed position the connections labeled 7 and 1 are electrically the same. This is the stop button as you will understand later.

(2) Normally Opened push button is the start button. There is a metal strap that provides an electrical connection across the one terminal of the normally closed and the normally opened switch. The normally open switch, when depressed, sends power to the holding coil.

b. The holding coil is located between connections 5 and 6 of our drawing. The holding coil just as a relays holding coil produces a magnetic field when electric current flows through it. Hence, the holding coil causes the normally open contacts to close using a magnetic field and holds them closed until energy is no longer delivered to the holding coil.

c. The normally opened contacts are located between connections 1 and 2, 7 and 8, 11 and 12, and 15 and 16. The normally open contacts close when the holding coil is activated.

(1) The contacts between connections 1 and 2 provide energy to the holding coil, once the holding coil has been activated by the normally open push button. The normally closed push button provides power through the normally open contacts between connections 1 and 2.

(2) The remaining normally open contacts provide a path to the motor windings, allowing it to operate.

d. The heaters are located between connections 9 and 10, 13 and 14, and 17 and 18. The heaters are in series with the normally open contacts and pass on power to the motor. The heaters monitor the current flow that is passed to the motor windings.

(1) During normal motor operation, the heaters do nothing. However, the heaters radiate heat if an overload occurs.

(2) If the motor draws excessive current the heaters cause a bi-metallic mechanism to trip that shuts off the motor.

e. Normally closed contacts are located between connections 3 and 4. These contacts open when the heaters cause the bi-metallic mechanism to trip. When this set of contacts opens the holding coil loses power and the normally open contacts open, disconnecting power to the motor.

12. IDENTIFYING MOTOR CONTROL MALFUNCTIONS

To identify or troubleshoot the cross line starter or a basic relay you must first know how the control operates and what voltages are at what connections. Furthermore, you must know what connection and components should have continuity. The operation of the cross line starter is as follows:

a. Before the cross line starter is activated, L1 can be found at the connections labeled 7 and 1 because the normally closed push button provides an electrical path. L1 is also found at the pole of the normally open push button opposite the connection that is electrically the same with the connection labeled 2.

b. L2 can be found at the connection labeled 11. It cannot travel any further until the normally open contacts found between the connections labeled 11 and 12 are closed.

c. L3 can be found at the connection labeled 15. It cannot travel any further until the normally open contacts found between the connections labeled 15 and 16 are closed.

d. When the normally open push button is depressed, electrical energy travels through the holding coil.

e. The holding coil becomes magnetized. Since the coil is being excited by alternating current, the core is equipped with a shading coil. Without this, the pulsating current would cause the starter to chatter. The shading coil allows the holding coil to maintain it's magnetic abilities on the reverse cycle. At this point if a voltage reading is taken at the connections labeled 5 and 6, then a potential between 110 and 120 volts should be found. The coil can be checked when power is off to check for open or shorted coil windings.

f. The magnetized coil causes all the normally open contacts to close. At this point voltage should be present at the connections 8, 12, and 16. A voltage reading between any two of these connection should show a potential of approximately 208 volts. If a voltage reading is taken between any of these connections and the connection labeled 6, then a potential of approximately 110-120 volts should be present.

g. Current now travels to the motor through all the closed contacts. It also allows current to continue to flow through the contacts at connections 1 and 2. This current path keeps the coil energizes when the normally open push button is released; thus, keeping the coil magnetized and the contacts closed.

h. There are three heaters, each are in series with a set of normally opened contacts and a motor winding of the three phase motor. These heaters are found between the connections labeled 9 and 10, 13 and 14, and 17 and 18. The heaters, under normal operation, do not heat up. To safeguard the circuit and the motor, the heaters heat up when too much current flows through them.

(1) When the heaters heat up they cause a bi-metallic strip to warp. These strips are connected on a spring loaded assembly that trips open the normally closed contacts at the connections labeled 3 and 4; thus, stopping the current flow to the coil.

(2) The overload that is tripped by the heaters must be reset by pushing the reset button.

a Failing to reset the over load will cause the normally closed contacts to remain opened. Therefore, when a reading across connections 3 and 4 is taken an open will be read on the ohm meter.

b When power is not flowing, an ohm meter can be used to ensure the heaters are not broken. They should give a reading equal to 0.00 resistance when reading across them. If the reading indicates an open, you should replace the heater.

i. The motor control can be shut off by pushing a normally closed push button switch. This stops current flow to the holding coil and dissipates the magnetic field.

j. Normally open contacts: They are located here on the block diagram between the connections labeled 1 and 2, 7 and 8, 11 and 12, and 15 and 16. When the cross line starter has not been activated no voltage should be found at the connections labeled 2, 8, 12, or 16.

k. Normally closed contacts: As mentioned earlier, there is one set of normally closed contacts for the cross line starter. They are found between the connections labeled 3 and 4. Continuity should be found between these connections when using an ohm meter. If there is no electrical connection between 3 and 4 then the reset button must be pushed in to reset these contacts back to the closed position.

l. Holding coil: The holding coil is located between the connections labeled 5 and 6. An ohm reading around 30.2 on the 200 ohm scale should be found between these connections. The ohm value may vary for the holding coil on other models of cross line starters.

m. Ground: We learned this symbol in previous classes. It is a good practice to connect the ground before wiring other connections.

n. Push Button Station: The push button station is made up of two push buttons

(1) The normally open push button is the start button. One pole of the switch is electrically the same as one of the poles of the normally closed push button. The connections labeled 7 and 1 are connected to this pole of the normally opened push button. The connection labeled 2 is electrically the same as the remaining pole of the normally open push button. If you follow the circuit down to connections 3, 4, and 5 you will see that they are all electrically connected.

(2) The normally closed push button provides an electrical connection between connection 7 and 1. Depressing this button while the holding coil is activated causes the holding coil to lose power, causing the normally open contacts to open , shutting off the motor.

13. REPAIRING MOTOR CONTROL MALFUNCTION: After a malfunction has been identified, the person performing the repairs must determine if replacing a component or rewiring a portion of the circuit is required. When changing a component the following must be done:

a. Ensure the power is off to the motor control and safe guard against reactivating by disconnecting the feeder or tagging and locking out the disconnect. If the disconnect is out of view of the person performing the repairs then it is a good ideal to post another person at the disconnect to ensure it is not turned back on.

b. If the component will have to be ordered, it is best if the old component remains intact. This prevents additional parts from being lost and aids the person who is replacing the part. Generally it's better to have the same individual remove the bad component and replace it in the reverse order.

c. When changing heaters you will need a flat head screw driver.

(1) remove the two screws that hold the heater in place and pull the old heater out.

(2) Place a new heater in the housing, ensuring the elements match the one removed, then replace and tighten the two screws.

d. If the contacts are burnt or damage then a new section will have to be ordered and replace the damaged one.

e. All wires that are replaced must be the same size as the ones that are damaged.