UNITED STATES MARINE CORPS
Utilities Instruction Company
Marine Corps Engineer School
Marine Corps Base
Camp Lejeune, North Carolina 28542-5040

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STUDENT HANDOUT

CONNECT ELECTRIC MOTORS

a. **Terminal Learning Objective**

(1) Provided with equipment containing electric motors, applicable tools, generators, test equipment, a multimeter, and the reference, connect an electric motor, so that there is proper phasing. (1141.03.09)

b. **Enabling Learning Objectives**:

(1) Provided a selection of definitions and component names, without the aid of reference, match the definitions to the correct component names, in accordance with Electric Motor Repair third edition and Industrial Motors. (1141.03.09a

(2) Provided a single-phase motor, motor trainer, and applicable tools, connect a single-phase motor to rotate clockwise, in accordance with Electric Motor repair third edition and Industrial Motors. (1141.03.09b)

(3) Provided a single-phase motor, motor trainer, and applicable tools, connect a single-phase motor to rotate counterclockwise, in accordance with Electric Motor repair third edition and Industrial Motors. (1141.03.09c)

(4) Provided a three phase motor, motor trainer, and applicable tools, connect a three phase motor to rotate clockwise, in accordance with Electric Motor Repair third edition and Industrial Motors. (1141.03.09d)

(5) Provided a three phase motor, motor trainer, and applicable tools, connect a three phase motor to rotate counterclockwise, in accordance with Electric Motor Repair third edition and Industrial Motors. (1141.03.09e)

1. **Electric Motor Components**

a. **The stator** is one of the main parts of the electric motor. The stator is made up of thin laminated sections of soft iron or steel that are all pressed together and form the core of an electromagnet. Insulated copper wire is than wrapped around the core to form windings. 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. A full value of each magnetic pole occurs during each alteration. There are two alterations per cycle and the standard electrical frequency of alternating current in the United States is 60 hertz. Therefore, each second the polarities are changing 120 times.

b. **The rotor** is the another main part of the motor. The rotor is the part of the motor that spins. There are two types of rotors.

(1) **Squirrel cage rotors** 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 electromagnet.

(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 considered motion

2 The **second** thing needed to produce 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 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 brought together in an electrical circuit with one another. This is accomplished by the rings that are electrically and physically connected to the metal bars at both ends of the rotors.

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 of rotor we will be talking about is called an armature. Unlike the squirrel cage, it is wire wound.

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

(b) The commutator makes the connection to these windings, 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 the 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 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, brushes and slip rings, depending on the type of motor. They also house the bearings.

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. Cooling fan can be external as well as internal depending on the type of motor.

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 causes 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 causes 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. We will see how this device works later on in the class.

2. **<u>Operation of a Split Phase Motor</u>**:

a. The way in which a rotating magnetic field is created is reflected in the name of the motor. The first type of motor we will look at is the single phase, split phase motor. As the name implies this motor uses single-phase power and splits the current by passing it through two sets of windings that are in parallel.

(1) Single-phase power first enters the stator through he line conductors, L1 and L0. The stator is made up of two copper windings that are connected in parallel. These winding are known as our start and run windings.

(2) The start windings are made of a thinner wire and has less inductive reactance than the run winding; thus, allowing the start windings to become magnetized before the run windings.

(3) The run winding is made of thicker wire and has more turns than the start winding. This design gives the run winding more inductive reactance and causes the current in the run winding to lag the current through the start winding.

(4) In a split phase motor the start and run windings are spaced one after the other so that the start winding magnetizes first, and then the run winding magnetizes, which creates a magnetic field that rotates around the stator.

b As we know, the rotating magnetic field of the stator induces the rotor through electromagnetic induction and the rotor sets up its own magnetic poles. The magnetic poles of the rotor oppose the magnetic poles of the stator. Since the stator magnetic poles are rotating, the rotor turns as it is pushed from one pole to the next around the stator.

c Once the rotor has reached about 75% of its full speed, a **centrifugal switch** which is placed in series with the start winding opens and stops the current flow through the start winding. Since the motor now has momentum the run winding is all that is needed to keep it turning.

3. **Operation of a Capacitor Start Motor**:

a. Like the split phase motor, single-phase power enters the stator through L1 and L0.

(1) The start and run windings are similar in size and the number of turns. The timing difference of the current through the two windings is created by placing a capacitor in series with one set of the windings in which we will call our start winding.

a Since the start winding has more capacitive reactance than the run winding, it will be magnetized before the run winding.

b. The remaining operation of the capacitor start motor is the same as the split phase motor:

(1) The stator sets up its rotating magnetic field.

(2) The magnetic lines of flux from the stator cut through the rotor causing a voltage to be induced in the rotor.

(3) The induced voltage in the rotor causes current to flow through it.

(4) The current flow through the rotor is surrounded by a magnetic field that opposes the magnetic field of the stator.

(5) The opposing magnetic field of the stator pushes the rotor from one pole to the next as the stator magnetic field moves from one pole to the next.

(6) At about 75% of the rotors full speed, a centrifugal switch opens and stops the current flow through the start winding.

4. **Connecting Single Phase Motors**

a. In all single phase motors the run and start windings are connected in parallel. Therefore the hot line or L1 will be connected to the beginning of each winding and the neutral line or L0 will be connected to the end of each winding.

(1) The windings on all motors will have connection leads that are usually marked numerically but sometimes leads can be color-coded.

(2) The run windings will be marked T1 and T4 or blue and yellow respectively.

(3) The start windings will be marked T5 and T8 or black and red respectively.

b. The windings will be connected as follows:

(1) L1 will connect to T1 and T5, if color-coding is used L1 will connect to blue and black leads.

(2) L0 will connect to T4 and T8, if color-coding is used L0 will connect to yellow and red leads.

5. **Reversing Single Phase Motors**:

a. To reverse the rotation of a split phase and capacitor start motors, all we have to do is change the current flow through one of the windings. This can be done by simply switching the leads to the run winding and connect L1 to T5 and T4 or the yellow and black leads, and connecting L0 to T1 and T8 or the blue and red leads.

6. **Operation of a Three Phase Motor**:

a. The next type of motor that we are going to look at is the three-phase motor. As the name applies, the three-phase motor uses three-phase power instead of using single-phase power like the split phase and capacitor start motors.

(1) As we already know the three-phase power uses three hot lines L1, L2, and L3. We also know that all the phase's peak in sequence.

(2) Because the three phases peak in sequence it is not necessary to use different types of windings to create a rotating magnetic field within the stator. All that we have to do is place three sets of windings in the stator and space them at equal distances from one another. Then we need to connect each winding to it’s own hot lead. Since three phase power peaks in sequence the windings will

magnetize one after the other, which creates a rotating magnetic field.

b. The stator winding of the three-phase motor all have the same size wire.

c. The stator winding of the three-phase motor all have the same number of turns.

d. The stator winding of the three-phase motor contains no start winding or centrifugal switch.

(1) Since the windings of the three phase motor receive current in sequence from L1, L2, and L3 the rotating field is created without the need to place special windings in the stator.

(2) Since there are no special windings in the stator of a three-phase motor, there is no need for a centrifugal switch.

(3) All the windings in the three-phase motor are all run windings.

7. **Connecting Three Phase Motors**:

a. The windings of a three-phase motor are connected in series and often each winding is divided into two parts. This allows the motor to be connected to a low voltage system, 120v/208v, or a high voltage system, 240v/416v.

b. In the utility field you will almost always be connecting motors to a 120v/208v system, therefore, this lesson will cover the 120v/208v connections only.

c. The winding of a three-phase motor will be in one of two configurations, the wye connection and the delta connection.

(1) To determine how a three phase motor should be connected you must read the motor nameplate that is attached to the motor.

a. A three-phase motor with its windings in a wye configuration will be connected as follows:

1. Connect L1 to T1 and T7, then connect L2 to T2 and T8, then connect L3 to T3 and T9, and tie T4, T5, and T6 together, finally make sure the motor frame has an equipment ground attached to it.

b. A three-phase motor with its windings in the delta configuration will be connected as follows:

2. Connect L1 to T1, T6 and T7, connect L2 to T2, T4 and T8, then connect L3 to T3, T5 and T9, finally make sure the motor frame has an equipment ground attached to it.

8. **Reversing the Three Phase Motor**

a. To reverse the rotation of a three phase motor all we need to do is interchange any two of the motor leads or you can interchange any two of the power leads.