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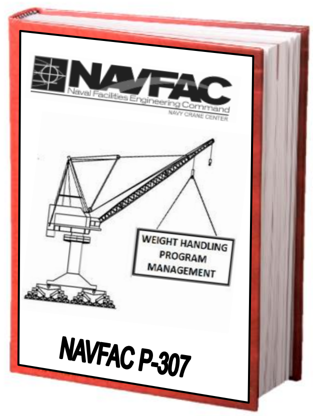

NAVFAC P-307 Training

CRANE ELECTRICIAN

WEB BASED TRAINING STUDENT GUIDE

NCC-CE-02

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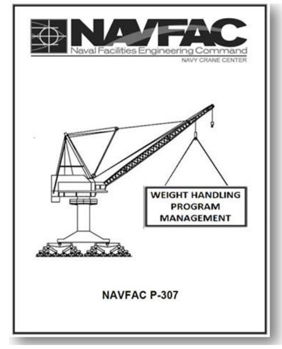
INTRODUCTION



Crane Electrician

WELCOME AND OVERVIEW

Welcome to the NAVFAC P-307 Crane Electrician course.

In this training course you will review the basic concepts and principles of electrical theory and electrical safety as well as various regulatory requirements that may impact electrical work on cranes such as those found in the National Electrical Code. You will be introduced to methods and techniques to safely and correctly perform maintenance, troubleshooting, and repair of electrical components like generators, alternators, motors, and controllers. You will be able to identify the different types of test equipment used when performing this type of work. Finally, you will learn about several kinds of fasteners, their applications, and the techniques used for their proper installation.

COURSE OBJECTIVES

The overall objective of Crane Electrician is to acquaint electricians with Navy requirements for the safe electrical maintenance of Navy cranes and provide a knowledge base on which to build upon with on-the-job experience.

COURSE MODULES

To support the objectives of this course and efficiently and effectively cover all the required information, this presentation is divided into fourteen parts, or modules. Each module title is listed below and includes:

- Lockout-Tagout
- Crane Electrical Safety 1, 2 and 3
- DC Motors
- DC Generators
- AC Motors
- Alternators
- Controllers
- National Electrical Code 1, 2 and 3
- Fasteners
- Electrical Test Instruments.

NOTES

HAZARDOUS ENERGY SAFETY

Welcome

Welcome to the NAVFAC P-307 Crane Mechanic training module: Hazardous Energy Safety.

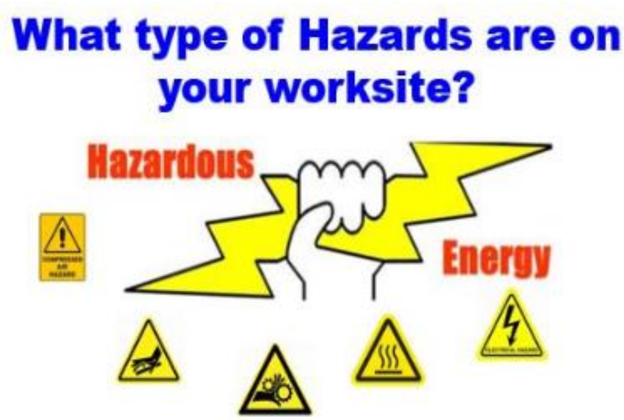
Hazardous Energy Safety Intro

What is hazardous energy? Hazardous energy is any source of energy (electrical, mechanical, thermal, kinetic and pneumatic) that can be hazardous to workers when discharged from a stored energy source. Failure to control the unexpected release of energy can lead to machine-related injuries or fatalities. The risk from these sources of energy can be controlled in a number of ways, including lockout-tagout policies and procedures.

Objectives

Upon successful completion of this module, you will be able to define hazardous energy. You will know what questions to ask yourself to determine if you are fully trained and qualified to perform hazardous energy work. You will become familiar with several OSHA, NFPA, and Navy standard requirements. You will be able to explain the basic concepts of lockout-tagout. You will be able to define a qualified worker, authorized worker, and affected worker.

Hazardous Energy Safety Work Hazards



How to identify the hazardous energy in your worksite?

Here are some examples, both general and specific, of the types of questions you may want to ask yourself before starting work.

Is there any electricity present? Is there pneumatic energy present? Is there kinetic (stored) energy present? Is there any other type of stored hazardous energy? If I disassemble this component, will there be any spring tension or pressure released? Before I release this brake is there an additional measure (second brake, tie back, bar in the drum, spud or wind lock, etc.) I can employ to prevent uncontrolled movement (of hoist, boom, rotate, etc.)? What could happen if I disassemble a component without control measures in place?

Is there any special PPE, tooling, guarding, training or procedures, supervision, etc. needed to mitigate the risks associated with accomplishing this type of work?

Qualified and Unqualified Persons

Crane mechanics work on many types of cranes. Most cranes have electrical systems that use either AC, DC, or both AC and DC. Mechanical personnel may work on mobile crane electrical systems. Most mobile cranes contain less than 50 volts. Regardless of the type of crane, work on any system 50 volts or greater, requires a qualified person (i.e., electrician). Crane mechanics working on cranes with 50 volts or greater are normally not qualified to perform work on these types of electrical systems. Working on systems with less than 50 volts does not require the same energy controls. You can refer to the NFPA 70E, article 130.2 (A) 3 for equipment operating at less than 50 volts. A qualified electrician is required when working on any electrical system that is 50 volts or greater. Your activity will determine who is qualified.
A qualified person is one who has received training in, and has demonstrated skills and knowledge of, the construction and operation of electrical equipment and installations and the hazards involved, and how to mitigate the electrical hazards of working on or near exposed energized parts.

An unqualified person is one who has received little or no training in these types of electrical hazards and does not possess the knowledge, skills, and abilities to work on these types of electrical systems.
Your activity determines who is qualified to perform work assignments.

Lockout/tagout (LOTO)

Lockout/tagout (LOTO) is a safety process used to secure potentially hazardous energy on machinery, equipment, or systems. It requires that hazardous energy sources be "isolated and rendered inoperative" to prevent the uncontrolled release of energy, prior to beginning maintenance or repair work. The hazardous energy sources are isolated, locked and tagged out in the proper position. The locks used identify with the worker that placed the lock on the isolation point. The worker holds the key to the lock and removes the lock when the work is complete. When lock(s) and tag(s) are removed, the system may be returned to normal operation. This prevents accidental release of hazardous energy or the potential start-up of a machine while maintenance is being performed.
Lockout/tagout is performed by authorized employees. Authorized employees are trained and knowledgeable on the equipment and system that they are working on. They understand the importance of lockout/tagout and they are authorized per the activity to install locks and tags. The activity determines who is an authorized employee.
What are affected employees?

Affected employees are those personnel who may be affected by the action of a lockout/tagout. This includes employees who normally operate or use the equipment or system that is going to be locked out or tagged out while maintenance is being performed. For example, personnel who use cranes as a tool to perform their everyday work and may be impacted (or affected) by a lockout/tagout.

Disconnecting or making the equipment safe involves the removal of all energy sources. This is commonly referred to as isolation. For example, mobile crane battery disconnects isolate the battery's energy from the crane's electrical system and may be considered an isolation point. The steps necessary to isolate equipment are often documented in an isolation procedure or a lockout tagout procedure. The isolation procedure generally includes the following tasks:

• a. Announce shut off (warn affected employees)
• b. Identify the energy source(s)
• c. Isolate the energy source(s)
• d. Lock and tag the energy source(s)
• e. Prove that the equipment isolation is effective or it has reached a zero energy state.

Each activity shall establish, document, and implement a lockout/tagout program. The lockout/tagout program shall specify lockout/tagout procedures to safeguard workers from exposure to hazardous energy and the accidental release of these energy sources.

Standards and Procedures

There are several high level directives that must be followed which we will briefly discuss. Bottom line is that you will follow the local instructions, standard operating procedures (SOP), and original equipment manufacturer (OEM) manuals provided by your activity, etc.
The OSHA standard for the Control of Hazardous Energy (lockout/tagout) is found in 29 CFR 1910.147. This standard addresses practices and procedures necessary to disable machinery and prevent the release of potentially hazardous energy while maintenance or servicing activities are performed.
Other OSHA standards that contain energy control provisions are 29 CFR 1910.331, .332, and .333. In addition, some standards relating to specific types of machinery that contain de-energization requirements include 29 CFR 1910.179 (l) (2) (i) (c) which requires the switches to be "open and locked in the open position" before performing preventive maintenance on overhead and gantry cranes. The provisions of Part 1910.147 apply in conjunction with these machine-specific standards to assure that employees are adequately protected against hazardous energy.
NFPA 70E addresses electrical safety work practices and is widely considered as the standard for Electrical Safety in the Workplace. This standard focuses on practical safeguards that also allow workers to be productive within their job functions. NFPA 70E Article 130.2(3) provides the work practices on systems or equipment with less than 50 volts.

The Department of the Navy issued OPNAVINST 5100.23, which includes Prevention and Control of Workplace Hazards, Energy Control Program (LOTO) and Weight Handling Equipment.

Summary

Use caution when working on or near systems or components that may contain hazardous energy.

Your activity provides the training necessary for employees to perform the work they are assigned. Always check with your supervisor to ensure you have the proper training, qualifications and tools to perform that work as well as any required safety checks and procedures.

Local safety policies, OEM manuals, SOPs, work documents, etc., developed by or for your activity will most likely have all the higher-level OSHA, Navy, and industry requirements built-in. Your local instructions and work documents should provide all the necessary rules, regulations, definitions, and restrictions that you need to know for the work you perform. Your safety office, supervisor, engineering or Inspection and QA offices should have these documents and references available.

Knowledge Check

The next several screens contain questions relating to the covered material. Check your comprehension of the course content by answering these questions.

1. True or False. Failure to control the hazardous energy can lead to machine related failures or fatalities.

    A. True
    B. False

2. Select all that apply. Job work hazards include which of the following?

    A. Electricity
    B. Pneumatic
    C. Kenetic
    D. Spring Tension

3. Select all that apply. What are attributes of a qualified person?

    A. Received training
    B. Demonstrated skills and knowledge of equipment
    C. Familiar with hazards involved
    D. Activity will identify who is qualified

4. True or False. A unqualified person is one who has trained and possess knowledge, skills, and abilities of the work that is being performed.

    A. True
    B. False

5. Select all that apply. Lockout/tagout (LOTO) is a safety process used to secure potentially hazardous energy …

   A. By preventing the uncontrolled release of energy, prior to beginning work
   B. When hazardous energy sources are isolated, locked, and tagged in the proper position
   C. And is performed by authorized employees
   D. When locks and tags are removed, the system may be returned to normal operation

6. True or False. No activity shall establish, document, and implement a lockout/tagout (LOTO) program.

   A. True
   B. False

7. True or False. Lockout/tagout (LOTO) programs shall specify LOTO procedures to safeguard workers from exposure to hazardous energy and the accidental release of these energy sources.

   A. True
   B. False

LOCKOUT/TAGOUT

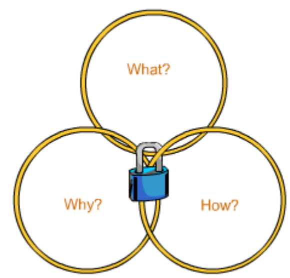
Learning Objectives

Upon completion of this module you will be able to:

- Define Lockout/Tag-out
- Understand basic Lockout/Tag-out procedures
- Recognize when they are required
- Know the difference between affected and authorized personnel
- Control potentially hazardous energy
- Identify Lockout/Tag-out devices
- Understand basic procedures for re-energizing systems when lockout tag-out is no longer required.

Overview

The purpose of the lockout/tagout system is to control hazardous energy and prevent injury to personnel.



Lockout procedures are a principle means of controlling energy hazards. A lockout procedure is a set of safe work practices and rules that makes it impossible for a worker to come into contact with an uncontrolled energy source.

WHAT? The lockout procedure blocks the flow of energy from a power source to a piece of equipment and keeps the power source blocked.

WHY? Every year people are killed in accidents resulting from unexpected start up or energizing of equipment.

HOW? Notify all employee who may be affected. Disconnect and remove energy. Lockout and tagout energy. Ensure energy does not affect workers during service or maintenance.

Personnel Involved

Affected employees are those who work in the area of the equipment or system that will be locked out or tagged out. An affected employee has no authority to install or remove lockout/tag-out devices or tags.

Authorized employees are the only personnel who are approved to perform lockout/tag-out procedures. They are authorized to perform these procedures to place the components or systems, which they will be servicing, in a safe condition.

When required?

Lockout/tagout procedures are required when the safety of personnel may be affected by hazardous energy during servicing and maintenance of WHE.

Lockout/tagout procedures shall conform to OPNAVINST 5100.23 and shall have the concurrence of the activity safety office.

Lockout/tagout procedures are required when any: guard or safety device is removed or bypassed; body part is placed in a point of operation; unprotected body part is placed in a panel with exposed electrical conductors; or when an associated danger zone exists during operation.

Exceptions:

Minor adjustments or servicing, for example the idle (rpm) adjustment to an engine that requires the engine to be running, or lubrication services

Hazardous Energy

Hazardous energy may include all of these sources around your workplace.

- Electrical
- Pressurized liquids and gases
- Hydraulic
- Pneumatic

Kinetic Energy – blades, belts, and fly wheels. Energy that keeps an object moving after power supply is cutoff.

Potential Energy – raised loads, counterweights, springs, capacitors, accumulators

ENERGY ISOLATING

Energy Isolating Devices

Energy-isolating devices disconnect or shut down the energy source to the equipment that must be serviced.

Acceptable energy isolating devices: manually operated circuit breaker, manually operated switch, disconnects load conductors from all ungrounded supply conductors, no pole can be operated independently, disconnect switch, line valve

Unacceptable energy isolating devices: push buttons, selector switches, other control circuit type devices. Why are the examples unacceptable? Because they can be operated by anyone and they do not lockout without attaching additional devices.

Lockout

The preferred method to prevent hazardous energy from injuring personnel is lockout. Lockout means locking an energy isolating device in a safe position.

What is lockout? The locking an energy isolating device in a safe position. Locked off or in a disconnected position. Ensures equipment cannot be operated.

When is lockout used? Energy isolation devices shall be locked unless it is not capable of being locked or if the employer can demonstrate that the use of a tagout system will provide the same protection as a lock.

Devices: are only used for controlling energy; they are provided by the employer; only authorized employees can perform lockout/tagout.

Tagout

Tagout is the placement of a tag on an energy isolating device.

What is tagout? The placing of a tag on an energy isolating device. It identifies who is working on the equipment and indicates that the equipment may not be operated.

When is tagout used? When an energy isolating device is not capable of being locked out.

Devices: must be standard throughout facility, clearly and uniquely marked, and identifiable.

Device Requirements

Lockout/tagout devices must meet these requirements.

- Only used for controlling energy
- Provided by the employer
- Standard throughout the facility
  - Clearly and uniquely marked
  - Identifiable
- Labeled to identify the person installing the device
  - Only one person can use the device
  - Only removed by the person who installed the device
- Substantial
  - Prevents removal
  - Durable

PROCEDURE

Lockout/Tagout Procedures

The lockout/tagout system includes three fundamental procedures: 1) preparing for the lockout/tagout, 2) executing the lockout/tagout, and 3) re-energizing the equipment or systems.

1. Preparing for lockout/tagout: notify affected employees; prepare for shutdown; shut down the equipment

2. Executing lockout/tagout: isolate the equipment, apply the device (lockout/tagout), relieve stored energy; mitigate arc flash potential; verify isolation

3. Re-energizing equipment or systems: prepare site for re-energizing; ensure safety of personnel; remove devices; issue warnings and notify others

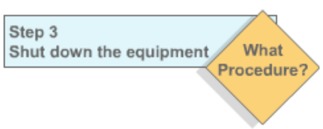
PREPARING FOR LOCKOUT/TAGOUT

Lockout/Tagout Procedures

There are three steps in preparing for the lockout/tagout.

Step 1: Notify affected employees. These are the people who use the equipment. Notify everyone in the affected area.

Step 2: Prepare for shutdown. Identify and locate all energy sources. Check for alternate energy sources. Identify and locate all energy isolation devices.



Step 3: Shut down the equipment. Use procedures established for the equipment. Proper shutdown helps avoid additional or increased risks.

EXECUTE LOCKOUT/TAGOUT

Executing

There are five basic steps when executing lockout/tagout procedures. Remember to always follow your local policies and procedures.

Step 1: Prepare for shutdown (*step 2 on the screen*)

- Identify and locate all energy sources
- Check for alternate sources
- Identify and obtain proper energy isolation devices
- Identify and locate any stored energy

Step 2: Isolate the equipment *(step 1 on the screen)*

- lockout and isolate or shutdown all energy sources

Step 3: Apply the device

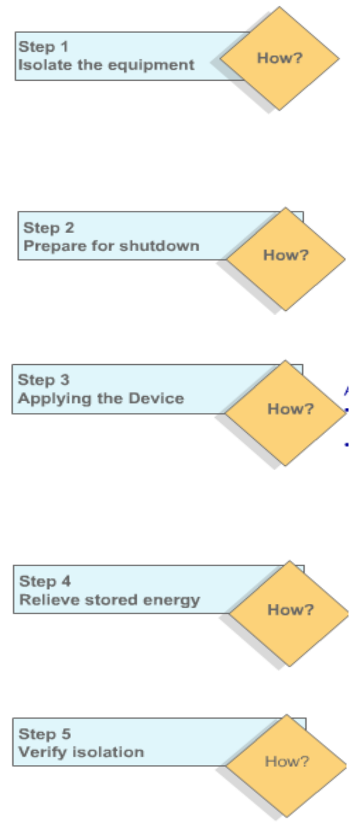
- Locks and tags shall be attached to each energy isolation device
- Must hold the device in the "safe" position
- Tags should clearly indicate operational restrictions
- Tags should be located at the same point a lock would be attached

Step 4: Relieve stored energy

- Release or restrain stored and potential energy
- Block up/suspend affected parts or components (secure)

Step 5: Verify isolation

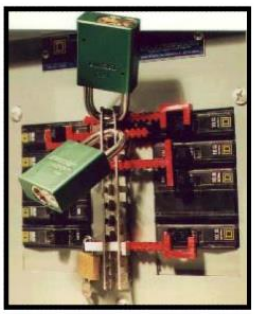
- Test equipment to see if it operates and to ensure energy isolation is satisfied
- Attempt to start equipment using normal start-up procedures
- Continue to release stored energy is re-accumulation is possible
- Return controls to the required position after verification is performed



Note: Although the requirements for lockout/tagout may be satisfied, additional safety requirements may need to be employed prior to the start of work, for example, arc flash requirements.

Special Considerations

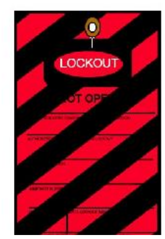
On the next few screens, review and follow any special considerations when performing lockout/tagout, such as the application of lockout devices and tags and the accomplishment of a group lockout/tagout.



Applying Devices

The lockout/tagout device must ensure that it holds the isolating device in a safe or off position.

Applying Tagout Devices



If only tagout is used, for example no locking device, the tag must be attached so that it clearly indicates that operation or movement of the energy isolating device is prohibited.

It must be attached at the same point where a lock would have been attached.

If the tag cannot be attached directly to the energy isolating device, attach it as close as safely possible in a manner that is immediately obvious to anyone attempting to operate the device.

Performance by Group

When lockout/tagout procedures must be performed by more than one person, each worker is required to attach their own personal lockout/tagout out device. One person shall be responsible to oversee the procedure.

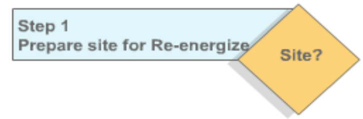
RE-ENERGIZE

Re-energizing

The final procedure in the lockout/tagout system is to re-energize the equipment or systems. There are four steps to accomplish this.

Step 1: Prepare to re-energize

- *Remove all non-essential items such as tools and parts*
- *Ensure equipment and components are operationally intact*
- *Verify controls are in neutral*



Step 2: Ensure safety of personnel

- *Notify all affected employees*
- *Ensure personnel are in a safe position or removed from the area*

Step 3: Remove devices

- *Authorized employees shall remove lockout/tagout devices*
- *Remove any blocking or lashing installed for the control of potential energy*

Step 4: Issue a warning:

- *Warn affected employees that the equipment is about to restart*

SUMMARY

Lockout/Tagout Review

Review the summary for lockout/tagout systems.

What:
The lockout procedure blocks the flow of energy from a power source to a piece of equipment and keeps the power source blocked.

Why:
Every year people are killed in accidents resulting from unexpected start up or energizing of equipment.

How:
- Notify all employees who may be affected
- Disconnect and remove energy
- "Lockout" and "tag-out" energy
- Ensure energy does not affect workers during service or maintenance

Preparing for Lockout/Tag-out
- **Notify** affected employees
- **Prepare** for shutdown
- **Shut** down the equipment

Executing Lockout/Tag-out
- **Isolate** the equipment
- **Prepare** for shutdown
- **Apply device**: the lockout or tag-out
- **Relieve** stored energy
- **Verify** isolation

Re-energizing equipment or systems
- **Prepare** site for re-energizing
- **Ensure** safety of personnel
- **Remove** devices
- **Issue** warning

NOTES

Lockout/Tagout Knowledge Check

Online questions may appear in a different order that those shown below.

1. Select the best answer.

The purpose of lockout/tagout is to prevent personal injury which can be caused by all of the following examples except…

A. routine minor adjustments
B. rotating unguarded machinery
C. stored hydraulic energy
D. electric shock
E. pressurized gases or liquids

2. Select the best answer.

An employee places any part of their body into an area where the unexpected re-energizing or release of stored energy from machinery could result in injury. This situation requires…

A. no action
B. lockout
C. tagout

3. Select the best answer.

Whenever an employee is required to remove or bypass a guard or safety device. This situation requires…

A. no action
B. lockout
C. tagout

4. Select the best answer.

Which of the following person is responsible for applying locks or tags to machinery, equipment, or systems?

A: only the worker's supervisor
B. affected employee
C. authorized employee

5. Select the best answer.

Which of the following does not meet the requirements for a lockout device?

A. provides caution against energizing
B. substantial enough to prevent easy removal
C. equipment cannot be operated until device is removed
D. locks source in the "off" position

6. Select the best answer.

'Identifies attaching person' is a characteristic of a…

A. lockout tag
B. lockout device
C. lockout tag and lockout device

7. Select the best answer.
Provides positive control is a characteristic of…

A. a lockout tag
B. a lockout device
C. a lockout tag and a lockout device

8. Select the best answer.
Identify any of the following statements that are not a requirement for lockout/tagout devices.

A. must only be used for controlling energy
B. are provided by the employer
C. only removed by the person who places them
D. must not be used for any other purpose
E. must contain a phone number
F. must identify the person using them

9. Select the best answer.
When an isolation device has locking capability, a _____ is required.

A. lockout procedure
B. tagout procedure
C. latching procedure

10. Select the best answer.
When an isolation device has no place for a lock; a __________ is required.

A. lockout procedure
B. tagout procedure
C. latching procedure

11. Select the best answer.
When equipment must not be operated or energized; a _____ is required.

A: lockout procedure
B. tagout procedure
C. latching procedure

12. Select the best answer.
Who must be notified before a lockout/tagout procedure is started?

A: affected employees
B. everyone who uses
C. all people in the area where the work is to be done
D. all listed personnel

13. Select the best answer.
In performing a lockout/tagout procedure, the first step is…

A. notify affected employees
B. apply the lockout or tagout device
C. shut down the equipment
D. relieve stored energy
E. verify isolation

14. Select the best answer.
When performing the lockout/tagout procedure, before you relieve stored energy you must…

A. verify isolation
B: relieve stored energy
C. apply the lockout or tagout device

15. Select the best answer.
When performing the lockout/tagout procedure, the last step performed is to…

A. verify isolation
B. notify affected employees
C. shut down the equipment
D. apply the lockout or tagout device
E. relieve stored energy

16. Select the best answer.
Who must be notified before re-energizing equipment that has been locked out or tagged out?

A. all who use the equipment
B. everyone in the work area
C. affected employees
D. all listed personnel

17. Select the best answer.
Who is authorized to remove lockout or tagout devices?

A: the authorized employee who installed the device
B. all operators of the equipment
C. anyone authorized to fix the equipment
D. affected employees
E. only the worker's supervisor

CRANE ELECTRICAL SAFETY 1: PRINCIPLES AND POLICIES

LEARNING OBJECTIVES

Upon successful completion of this lesson, you will be able to describe the…

- industry standards for electrical safety
- part you play in that electrical safety program
- basic principles of electricity and how they impact an electrical safety program
- effects of electrical current on the human body

STANDARDS

Electrical Safety Polices

Your local electrical safety policies should be more than your supervisor requiring that everyone "work safe" or shop personnel telling their supervisors that they always follow all the rules. They should be more than management hoping to make it through another quarter without an accident. Electrical safety policies should be written down in compliance with governing standards and available to all workers.

Industry Standards

Electrical safety policies are required to be in compliance with the following standards:

- Title 29 CFR, Section 1910, Subpart S: Electrical Safety
- OPNAVINST 5100.23, Navy Safety and Occupational Health Program
- NAVFAC P-307, Weight Handling Program Management

Policies

Each Navy activity shall adopt the requirements of OPNAVINST 5100.23 as a minimum.

If additional requirements are identified by an activity, they shall be included in their local safety manual.

Where available publications do not cover an activity's specific needs, then the activity shall prepare requirements and include them in their respective safety manual.

HAZARDS

Crane Hazards

Some electrical hazards that you encounter are easy to spot. The exposed conductors in this picture are made up of a span wire system, including a pickup staff and pickup shoes. These are obvious hazards and you must not come into contact with them while they are energized. Adequate safety precautions for these and other obvious safety hazards must be taken.

Hidden Hazards

Electrical hazards on cranes may not be obvious. OSHA requires exposed electrical conductors on or near a work floor to be guarded to ensure workers do not come in contact with them. By elevating equipment greater than 8 feet and restricting access to 'authorized workers only', cranes are released from this standard. Cranes are not designed to protect onboard workers in areas other than the operator's cab.

Maintenance personnel are often onboard the crane in many locations other than the cab. Therefore, workers providing maintenance or performing repairs on cranes may be exposed to many types of hazards including electricity.

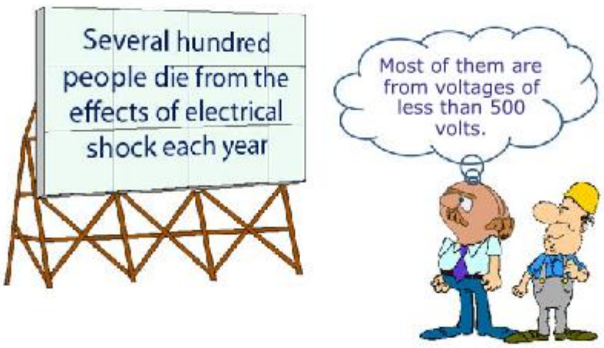
Workers should be trained in safety policies, procedures and hazard identification or mitigation principles.

Electricity Is Dangerous

Electricity is dangerous. The electrical power found on cranes is sufficient to cause injury or death. Electrical shocks can lead to falls. Due to the heights involved with crane maintenance and the remote areas where cranes may be located, a shock received by a worker may go unnoticed allowing an injury to turn into a fatality.

Why Electrical Safety?

You claim that you have never been electrocuted so why should you be concerned? Let’s take a look at some facts.



Electrocutions Do Happen

Several hundred people die of the effects of electrical shock each year. Most of them are electrocuted from systems that have less than 500 volts.

ELECTRICITY: OHM'S LAW

Electricity

Electricity works according to Ohm's law. In the early nineteenth century, Georg Ohm proved that a precise relationship exists between current, voltage, and resistance. This relationship is called Ohm's Law.

Ohm's Law

Ohm's Law relates the properties of electricity and is expressed using the formula E = IR, where E represents voltage, I represents amperage, and R represents resistance.

E = I x R

Relates the Properties of Electricity

- E = Voltage — Measured in Volts
- I = Current — Measured in Amps
- R = Resistance — Measured in Ohm's

Voltage is the force that causes electrons to flow. Voltage is represented by the letter E and is measured in volts. Current is the flow of electrons. Current is represented by the letter I and is measured in amps. Resistance is the opposition to current flow. Resistance is represented by the letter R and is measured in ohms.

Ohm's Law simply states that one volt will cause one amp to flow through one ohm of resistance.

Ohm's Law Equations

Using the equation for Ohm's Law, to determine volts, you would multiply amps and ohms, to determine amps you would divide volts by ohms and to determine ohms you would divide volts by amps.

E=IR   I=E/R   R=E/I

Constant Resistance

$$R = \frac{E}{I}$$

Ohm's law, I = E / R, provides that with a constant resistance, R, an increase or decrease in voltage, E or current, I will result in a corresponding increase or decrease in the other factor in the equation. In other words, E and I have a proportional relationship with constant R.

Example:

When I = 6 and E= 6 then R = 1, When I is increased to 12 and R is constant at 1, E will increase to 12 and vice versa when E is increased to 12, I will increase to 12.

Constant Voltage

$$E = IR$$

Ohm's law, I = E / R, provides that with a constant voltage, E, an increase or decrease in resistance, R, will result in a corresponding yet opposing decrease or increase in current, I. In other words, R and I have an inversely proportional relationship with a constant E.

Example:

When I = 6 and R= 2 then E is12, inversely, when I = 2 and R = 6 then, E = 12. When I is increased to 12 and R is decreased to 1, E remains at 12. Inversely, when I is decreased to 1 and R is increased to 12, E remains at 12.

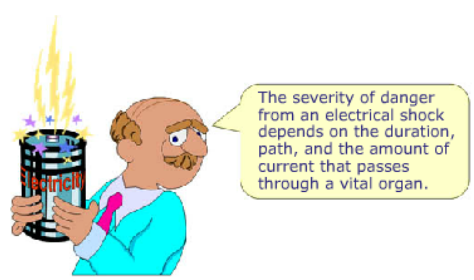
Resistance and Safety

Resistance is the property of electricity on which electrical safety is based. The worker cannot control the current or the voltage. Current is dependent on voltage and resistance. Voltage is set by the manufacturer. Resistance therefore is the only property the worker can control. Resistance should be kept as high as possible to reduce the worker's exposure to electrical hazards.

Dangers of Electrical Shock:

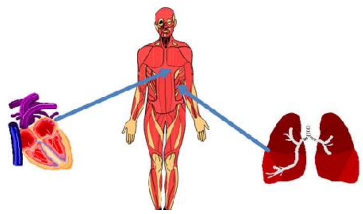
Current

The danger electricity poses to people occurs when current passes through a vital organ. The damage caused to the vital organ depends on the severity of the shock. The severity of the shock depends on the duration of the shock, the path the current takes through the body, and the amount of current present during the shock.



Duration

Duration is the length of time that current flows through the body. The longer a vital organ is exposed to a current, the more danger of damage or organ failure that may occur.



Path

Current that takes a path through the heart and the lungs poses the greatest risk. The heart and the diaphragm, which operates the lungs, receive electrical impulses from the brain that control their operation. Excessive current passing through the heart or diaphragm interferes with that operation. The brain and nervous system are the least affected by an electrical shock.

Contact Points

The contact points on the body through which electrical current enters and exits, determines the path current takes through the body. Current needs at least two contact points on the body. The hands are the most common points, because they are involved in doing the work. The feet are the next most common points because they usually provide the ground path.

Less Harmful

The path current takes is less harmful if the two contact points are a hand and a foot. In the picture of the body depicted here, yellow arrows indicate the less harmful path through the body. It shows the path entering through the hand, continuing through the arm, leg and exiting the foot on the same side of the body. This current path does not pass through the diaphragm, heart or other vital organs.

Most Harmful

The path current takes is most harmful if the two contact points are the hands. In the picture of the body depicted here, yellow arrows indicate the most harmful path because it passes through vital organs. It shows the path entering through the hand and arm, through the chest, heart and lungs, and continuing through the other arm and exiting from the opposite hand.

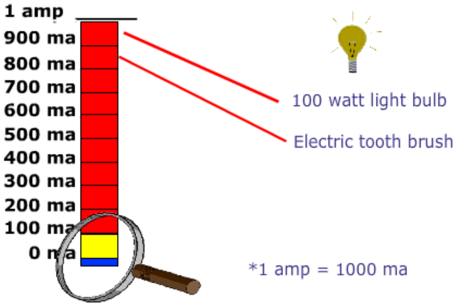
High Current

The severity of an electrical shock also depends on the amount of current. The more current that passes through a vital organ, the less likely the organ will survive.

Small Current Danger

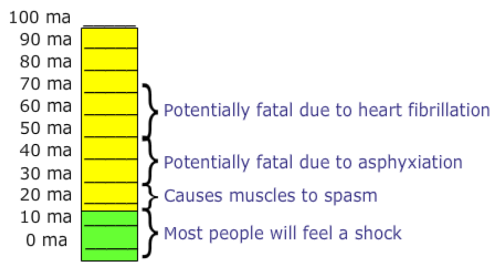
Amount of Current

To put things in perspective, let's look at some everyday objects and discuss the amount of current that they use and the potential dangers imposed by different amounts of current. Before we do that, you should know that amperages of less than 1 are measured in milliamps. One amp equals one-thousand milliamps. Milliamps are represented by the lowercase letters "m a". The scale on the screen is graduated in milliamps. Now, let's look at two examples of everyday objects you might use, a 100 watt light bulb and an electric toothbrush. A 100 watt light bulb requires about 1 amp of current while an electric toothbrush requires about 900 milliamps.



Electrical Safety - Small Current Danger

Now let's look at the dangers associate with exposure to currents less than 100 milliamps.



- At 0 to 20 ma most people will feel a shock.
- At 20-30 ma muscles can begin to spasm.
- At 30-50 ma, the current is potentially fatal due to asphyxiation.
- At 50-75 ma the current is potentially fatal due to heart fibrillation.

You cannot be too careful when working around electricity because even small amounts of current can be very dangerous, even fatal.

ELECTRICAL SAFETY REVIEW AND SUMMARY

During this module, you learned the basic requirements for electrical safety and the electrical factors that can affect your safety. The extent of injury to your body that may be caused by electricity depends on the path the current takes, the amount of current passing through the body, and the duration of the shock. You know the relationship between voltage, current and resistance as described in Ohm's Law. You understand that electrical hazards may not always be obvious and the current they possess, even in amounts as small as 25 milliamps can affect your body. Common household objects, that you may handle every day, require many times that amount of current to operate. Local activity electrical safety policies shall comply with governing standards, be in writing, and available to everyone. Electrical work, regardless of the amount of voltage or current present, can cause injury or death, if not performed safely.

NOTES

Electrical Safety Module 1 Knowledge Check

Online questions may appear in a different order that those shown below.

1. Select the best answer.

Electrical safety policies shall be written down, available to all workers, and _____.

A. filed in the equipment history file
B. labeled per ASME B30.19
C. comply with industry standards
D. posted in the crane cab

2. True or False

Electrical hazards on cranes may not be obvious.

A: True
B. False

3. Select all that apply.

Workers should be trained in…

A: risk mitigation
B. safety policies
C. hazard identification
D. customer service
E. tank cleaning

4. Select the best answer.

The amount of electrical power found on cranes is sufficient to cause death from electrical shock.

A. True
B. False

5. Select all that apply.

Ohm's Law relates voltage, current, and resistance. Regarding Ohm's Law, which of the following is/are true?

A: I=E/R
B. E=IR
C. R=AV
D. R=E/I

6. Select the best answer.

If current is determined by voltage, and the voltage is set by the manufacturer, what electrical property can you, the worker, control to mitigate exposure to electrical hazards?

A. amperage
B. voltage
C. resistance
D. current

7. Select the best answer.
The severity of an electrical shock is dependent upon which of the following conditions?

A. all listed items are correct
B. the duration of the shock
C. the amount of current
D. the path the current travels through the body

8. Select the best answer.
The most common contact points where electrical shocks enter and/or exit the body are…

A: shoulders and arms
B. torso and legs
C. head and neck
D. hands and feet

9. Select the best answer.
The most harmful path current can take through the body is…

A. in the hand, down the side of the body, out the foot
B. in the shoulder, down the side of the body, out the knee
C. in the foot, through the leg, out the thigh
D. in the hand, through the chest, out the opposite hand

10. True or False
As little as 30 milliamps can potentially cause death.

A: True
B. False

CRANE ELECTRICAL SAFETY 2: BRIEFINGS, QUALIFICATIONS, AND HAZARDOUS ENERGY CONTROL

LEARNING OBJECTIVES

Upon completion of this module you will be able to:

- identify the topics covered in a properly given job safety briefing, an electrical job briefing, when such briefings are required, and to what detail they must be provided
- identify employee qualification levels for performing various types of work on, in and around machines or equipment where electrical work is being performed
- discuss various hazard warning safeguards such as safety signs, tags, barricades and when safety attendants are required
- list and describe the five steps of a basic electrical energy isolation procedure, the simple three-step voltage check procedure, and the alternate voltage check procedure

JOB BRIEFING

Job Briefing

A minimum of one job briefing is required to be held at the beginning of the shift for planned routine work or at the beginning of each job before work begins. Repetitive or similar jobs may be briefed one time each shift. However, for work, that is non-routine, complex, more hazardous, or results in significant changes to the previously briefed plan, additional briefings shall be conducted as often as needed to maintain employee awareness and safety.

For routine work with easily recognized and mitigated hazards, briefings may be basic, so long as the employees involved possess adequate training and experience to perform the work and mitigate any hazards involved. Briefings shall be much more in depth if the work is or becomes more complex or when hazards are no longer easy to recognize and mitigate.

Job Briefing Coverage

In a job briefing, you and your supervisor shall discuss, as a minimum, the location and condition of the crane, materials, documentation, and the operational status of the crane. In addition, a copy of the signed WHE work authorizing document must be onsite. Any special requirements for additional tagging, set up, equipment, tools or personnel must be discussed. Finally, personnel must be made aware of any safety issues, including fall hazards, eye hazards, foot hazards, hearing hazards, and necessary personal protection equipment or PPE. This must also include an electrical safety briefing with specific electrical hazards and requirements.

ELECTRICAL SAFETY BRIEFING

Electrical Safety Briefing (1)

Reference: 2015 NFPA 70E Article 110.1(H) Job Briefing

An electrical safety briefing shall be conducted prior to starting any electrical work. The briefing shall include a discussion on required personnel qualifications, work authorization, and energy control and isolation requirements for the job.

The supervisor shall be aware of the requirements for performing the work and only assign personnel who possess the requisite qualifications to perform the work safely. The assigned worker has the responsibility to inform the supervisor of any question or concern regarding his or her qualifications to perform the work. The supervisor shall have a signed copy of the work authorizing document available during the briefing and provide it to the worker for his or her review. This review allows the worker and the supervisor to address and concerns with the assigned work. As part of the work discussion, the supervisor and worker shall agree that the work authorizing document shall be on the work site at all times while work is being performed. They shall also discuss and agree upon energy control and isolation measures. If necessary, the supervisor shall reiterate energy control and isolation policy.

Electrical Safety Briefing (2)

There are two types of energy isolation: simple and complex.

Simple isolation is utilized when all sources of energy are capable of being secured via lock or tag. In this case, no further actions are required.

Complex isolation is required when not all sources of energy can be secured by means of lock or tag. In this case, additional actions (or controls) such as watchstanders, special PPE, administrative controls, and/or documentation are necessary to ensure personnel safety.

TRAINING AND QUALIFICATION

Personnel who may reasonably be expected to face a risk of injury due to electric shock or other electrical hazards shall be trained in, and familiar with, the safety related work practices that pertain to their job assignments.

29 CFR 1910 addresses the qualification levels of personnel who work in, on, or around potential electrical hazards. The two levels of workers are unqualified persons and qualified persons.

Unqualified Person

Unqualified Person

An unqualified person is one who is NOT a qualified person. In other words, an unqualified person does not possess the requisite training, skills, knowledge, and experience in the construction, operation, installation, and use of electrical equipment and tools that a qualified person possesses. Unqualified persons shall be trained in and familiar with any electrically related safety practices which are necessary for their safety with respect to the job tasks they perform.

Unqualified persons are not authorized to perform the work of qualified persons.

Unqualified Person Training (1)

OSHA requires that unqualified persons be trained in the electrical safety-related practices that are necessary for them to safely perform their duties. Training may consist of but is not limited to briefings, attending general training on electrical safety, reviewing the activity safety handbooks, and/or reviewing electrical safety handbooks.

Unqualified Person Training (2)

Unqualified person training shall enable persons to correctly identify potential electrical hazards, personal protection requirements, and safeguards from hazards, electrical safety devices, and lock out/tag out or energy control procedures.

Unqualified Person Training (3)

Unqualified person training will help workers identify and avoid work that only qualified persons are authorized to perform. Training shall familiarize unqualified persons with electrical hazards, barriers, equipment and safety areas.

QUALIFIED PERSONS

Qualified Persons (1)

The second qualification level we need to discuss is that of the "qualified person". A qualified person, or in the context of this lesson plan, a qualified electrician, is one who has received training in and has demonstrated skill and knowledge in the construction and operation of electric equipment and installations and the hazards involved. Qualified persons are permitted to work on or near exposed energized parts.

Qualified Persons (2)

Only qualified persons may work on electric circuit parts and equipment that have not been de-energized under approved procedures. Such persons shall be…

- capable of working safely on energized circuits and
- familiar with the proper use of special precautionary techniques, personal protective equipment, insulation and shielding materials, and insulated tools

Qualified Persons (3)

Qualified persons shall be trained in, and familiar with, the skills and techniques necessary to determine the nominal voltage of exposed live parts; the clearance distances or approach distances specified by OSHA and the corresponding voltages to which the qualified person will be exposed.

Qualified Person(s) Skills

OSHA requires qualified persons to demonstrate the decision-making process necessary to determine the degree and extent of the hazard, the electrical safety equipment, and job planning necessary to perform the task safely. In addition to establishing and maintaining appropriate approach distances, the qualified person is also expected to recognize when approach distances alone are not adequate, when additional electrical safety equipment is required, and when to involve supervision in additional job planning in order to make each WHE maintenance task as safe as possible.

SAFEGUARDS

Safeguards

Safeguards shall be put in place to warn employees about hazards that may endanger them. These safeguards may include safety signs and symbols, locks, tags, barriers and barricades.

Barricades

Barricades such as tapes, cones, or A-frame type wood and/or metal structures provide a physical obstruction and control to a work area. Barricades shall be used in conjunction with safety signs to warn and prevent or limit employee access to work areas where they may be exposed to un-insulated, energized circuits or components.


Non-conductive barricades are constructed of materials, like plastic, that will not allow the flow of electricity.

Conductive barricades are constructed of rigid materials, like metal, that allow the flow of electricity. Conductive barricades, being stronger and sturdier, can be used in permanent locations. Conductive barricades are not permitted in areas where they may become an electrical conductor or pose any additional hazard.

Attendant Required

In some cases, an attendant may be required to warn and protect employees: when signs and barricades do not provide sufficient warning or protection from electrical hazards. Unqualified workers shall not cross approach boundaries unless briefed by a qualified person of all possible electrical hazards.

APPROACH DISTANCES

Qualified persons shall demonstrate an understanding of approach distances. Review the table for energized overhead line approach distances for AC voltage phase to phase.

Note that these approach distance apply only to qualified persons.

Unqualified persons shall remain a minimum of 10 feet away from overhead line voltages-to-ground of 50 thousand volts or below. Add 4 inches to the minimum approach distance for every 10 thousand volts above 50 thousand volts. Phase to phase voltages less than 50 volts do not have a specified approach distance.

Approach Distances

APPROACH DISTANCES FOR QUALIFIED EMPLOYEES

AC Voltage Range (phase to phase)	Minimum Approach Distance
300V or less	Avoid contact.
Over 300V, not over 750V	1 foot
Over 750V, not over 2kV	1 foot 6 inches
Over 2kV, not over 15kV	2 feet
Over 15kV, not over 37kV	3 feet
Over 37kV, not over 87.5V	3 feet 6 inches
Over 87.5kV, not over 121kV	4 feet
Over 121kV, not over 140kV	4 feet 6 inches

29CFR1910.333(c)(3)(ii) and Table S-5

HAZARDOUS ENERGY/ISOLATION

Qualified Person(s) Skills

Personnel who perform procedures for controlling hazardous energy by means of energy isolation shall be authorized to do so.

Authorized employees are persons who lock out or tag out machines or equipment in order to perform servicing or maintenance on that machine or equipment.

Affected employees are persons whose jobs require them to operate or use a machine or equipment on which servicing or maintenance is being performed under lockout or tag-out, or whose jobs require them to work in an area in which such servicing or maintenance is being performed.

Hazardous Energy Control/Isolation

Authorized employees shall receive training in the recognition of applicable hazardous energy sources, the type and magnitude of the energy available in the workplace, and the methods and means necessary for energy isolation and control.

Affected employees shall be instructed in the purpose and use of the energy control procedure.

All employees who work in areas impacted by energy isolation procedures shall be instructed on the procedure, the prohibition on restarting or re-energizing machines or equipment that are locked out or tagged out.

ELECTRICAL ISOLATION

Step 1 – Identify All Sources

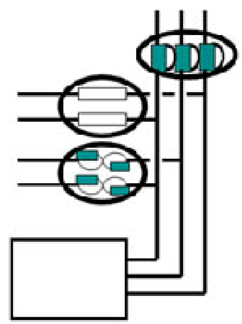
The first step in electrical isolation is to determine all the potential sources of electrical energy for a piece of equipment or system. Researching documentation on the equipment or system is effective in providing that determination. Further inspection of the job site, and knowledge of power distribution systems, aid in this determination.

Step 2 – Understand and Evaluate the Job

The second step in electrical isolation is job evaluation. To correctly establish the electrical isolation, the authorized employee/qualified person, which is one-in-the-same at this point, must evaluate and understand the systems and equipment involved. A lack of such understanding allows the possibility for a potential source of electrical energy could be overlooked. Although turning off all the power to the facility is an effective approach to electrical isolation, it is not a very practical approach. The authorized employee/qualified person's understanding of the job or task, allows an isolation that completely protects the workers involved in that job or task, but does not unnecessarily impact other workers, jobs or tasks. A knowledgeable evaluation of the equipment's location, will aid in correctly determining any additional precautions or equipment needed to establish the electrical isolation. The number and type of personnel involved in the task or job, will affect the type and extent of the electrical isolation.

Step 3 – Secure Power

The third step in electrical isolation is to secure the power. Locate the appropriate control devices necessary to establish electrical isolation [at the previously identified isolation points]. Evaluate the suitability, adequacy, and functionality or each device selected. For example, devices that can be easily or inadvertently operated, such as push buttons, master switches, and control handles, are not suitable isolation devices. In addition, removing a common fuse, by itself, is not adequate isolation because it can be easily replaced. However, covering or securing the empty fuse holders with a control device that is not easily defeated provides added reliability. Be sure that the selected control devices are free of defects or alterations. With power secured, set the control devices to the safe position and install the devices. Remember to note any discrepancies with labeling and documentation found during circuit verification and isolation.



ELECTRICAL ISOLATION (CONT.)

Step 4 – Establish Controls

Step four is to establish controls. To do this, attach locks and/or tags to the isolation control devices to establish positive and personal control of the hazardous energy.

Each worker must have his or her own individual locks/tags issued by the employer. These locks shall be identified via some type of serialization process that identifies to whom the locks are issued. Locks issued to employees for hazard protection shall not be used for any other purpose. Lockout and tag-out devices shall be standardized within the facility.

Establishing Controls – Tags (1)

Tags are essentially warning devices affixed to energy isolation devices and do not provide the physical restraint as that provided by locks. However, tags do possess the same amount of authority as locks and should never be violated. Tags should never be bypassed, ignored or otherwise defeated.

Each worker must have his or her own individual tags issued by the employer. Tags shall identify to whom they are issued. Tags issued to employees for hazard protection shall not be used for any other purpose. Tags shall be standardized within the facility. Tags will contain wording such as: “Do Not Operate”, “Do Not Open”, “Do Not Start”, etc., to warn against the hazardous conditions if the equipment were to be energized.

Establishing Controls – Tags (2)

Tags have spaces for recording vital information such as the isolation point, the purpose of the tag and the employee who is responsible for the tag. This information shall be legible and in sufficient detail to effectively convey all pertinent information. When attached to an energy isolation device, a tag shall not be removed without the authorization of the authorized person responsible for it.

Tags [and locks] shall only to be used by the person who owns them and only for work he or she performs during the work shift. Authorized employees shall affix their personal lock and/or tag when he or she begins work, and shall remove those devices when he or she stops working on the machine or equipment being serviced.

When the lock or tag owner is not available, the lock or tag may be removed under the direction of the employer, provided specific procedures for taking such actions are documented and comply with 29CFR1910.147.

Establishing Controls – Tags (3)

In the case of shift work, if there is no follow-on shift or personnel to attached their tags (and locks), and, the machine or equipment being serviced cannot be restored to a safe condition, a danger tag should be installed before the last personal tag is removed. Other danger or caution tags may need to be hung in other locations, such as the cab, to inform affected employees, such as the operator, of the current conditions, or restrictions, associated with the crane.

ELECTRICAL ISOLATION (CONT.)

Step 5 – Voltage Check

The fifth step in electrical isolation is verification - that is to verify that all electrical energy has been secured for the work to be performed. Verification of satisfactory isolation of electrical energy shall be done via voltage checks. **Voltage checks should be performed in accordance with local policies and procedures and only by qualified persons.** After setting isolation and prior to beginning work, check the machine or equipment being serviced for electrical energy. Any indications of electrical energy will require additional actions and considerations with regards to safely proceeding with any further work. Voltage checks may need to be performed in-process, as work is being completed, to re-verify system status. Voltage checks should always be done prior to beginning each work shift, anytime isolation has been de-established and re-established, or anytime an authorized employee has been away from the job site for any extended period of time.

Note: Voltage checks shall be performed while following OSHA standards and all local policies and procedures.

Voltage Check

A simple three-step voltage check procedure is discussed here. **Remember, voltage checks should only be performed in accordance with local policies and procedures and only by qualified persons.**

1. First, obtain a suitable voltage detection device, or meter. Test the meter's function on a known electrical power source.
2. Second, perform voltage checks on the isolated machine or equipment to be serviced to assure electrical energy is not present. Remember, any indications of electrical energy will require additional actions and considerations with regards to safely proceeding with any further work.
3. The third and final step is to re-verify the voltmeter is working properly by rechecking it on a known electrical power source.

Note: Local training and policies may dictate an alternate method to check for voltage including an understanding of the limitations of instrumentation to be used.

Alternate Voltage Check

If the third step of the previously discussed "three-step voltage check" cannot be performed in a practical manner, an alternate voltage check method may be used.

Using two voltmeters, follow steps one and two of the three-step method. The second voltmeter serves as validation for the readings obtained on the first meter - in-lieu of rechecking the first meter on a known source.

Note: Local training and policies may dictate an alternate method to check for voltage.

SUMMARY AND REVIEW

During this module we identified the topics covered in a properly given general job safety briefing and an electrical job briefing. We also discussed when such briefings are required and to what detail they must be provided. We identified employee qualification levels for performing various types of work on, in and around machines or equipment where electrical work is being performed. We discussed various hazard warning safeguards such as safety signs, tags, barricades and when safety attendants are required. To further facilitate the safe performance of your electrical duties, we discussed the five steps of basic electrical energy isolation, described a simple three-step voltage check procedure, and presented an alternate voltage check procedure.

NOTES

Electrical Safety Module 2 Knowledge Check

Online questions may appear in a different order that those shown below.

1. Select the best answer.

Job briefings shall be conducted…

A. when most of the personnel working the job are present
B. as time permits
C. during lunch
D. before beginning the shift or job

2. Select the best answer.

The depth of the pre-job briefing depends on…

A: whether work is routine or complex
B. the degree of difficulty in recognizing hazards
C. the effort required to mitigate hazards
D. all listed items are correct

3. Select all that apply.

Briefing topics shall include…

A. energy isolation/tagging
B. work authorizing documents/procedures
C. hazards/PPE
D. special tooling/considerations

4. True or False

An electrical safety briefing shall be conducted prior to starting complex electrical work and is not required prior to starting routine electrical work.

A: True
B. False

5. Select all that apply.

There is more than one type of energy isolation. They are…

A. singular
B. complex
C. simple
D. convoluted

6. Select the best answer.

Energy isolation that requires watchstanders, special PPE, administrative controls and/or additional documentation is categorized as what type of isolation?

A. convoluted
B. complex
C. simple
D. singular

7. Select all that apply.
29 CFR 1910 addresses the qualification levels of personnel who work in, on or around potential electrical hazards. They are:

A: experienced persons
B. qualified persons
C. non-experienced persons
D. unqualified persons

8. Select the best answer.
A(n) _____ does not possess the requisite training, skills, knowledge, and experience in the construction, operation, and installation of electrical equipment and tools that a qualified person possesses.

A. non-experienced person
B. unqualified person
C. experienced person
D. qualified person

9. Select all that apply.
Safeguards shall be put in place to warn employees about hazards which may endanger them. These safeguards may include…

A: symbols
B. barriers and barricades
C. tags
D. signs

10. Select the best answer.
A(n) _____ has received training in and has demonstrated skill and knowledge of the construction and operation of electric equipment and installations and the hazards involved and is permitted to work on or near exposed energized parts.

A. unqualified person
B. experienced person
C. non-experienced person
D. qualified person

11. Select the best answer.
_____ are the minimum amount of space a worker must keep between his or herself and energized electrical conductors.

A. approach distances
B. clearance zones
C. safe spaces
D. dead zones

12. True or False
Only affected employees are permitted to perform lockout/tagout procedures.

A: True
B. False

13. Select the best answer.
What category of employee performs jogs that require them to operate or use machinery or equipment on which servicing or maintenance is being performed under lockout or tagout, or whose jobs required them to work in areas where such servicing or maintenance is being performed?

A: unqualified employees
B. authorized employees
C. affected employees
D. qualified employees

14. Select all that apply.
Which item below is not one of the five basic steps to energy isolation?

A: barricade energy isolation points
B. establish controls
C. identify energy sources
D. evaluate work and isolation points
E. securing power
F. verify isolation via voltage check

15. Select all that apply.
Identify the true statement(s) regarding tags used in the energy isolation process.

A. tags shall identify to whom they are issued
B. each worker must use his or her own individual tags
C. tags will contain wording such as “Do Not Operate”
D. all the statements are true
E. tags shall be standardized
F. more than one person can use a single tag

16. True or False
Any person may perform voltage checks.

A: True
B. False

17. Select all that apply.
Assuming you are qualified to perform voltage checks and you have obtained a suitable voltmeter, what are the three basic steps for performing a voltage check?

A: re-verify the meter on a known voltage source
B. set the meter scale to the expected level of current
C. perform voltage check
D. test the meter on a known voltage source
E. clip the leads to the energized conductors

CRANE ELECTRICAL SAFETY 3: PRACTICAL APPLICATION

LEARNING OBJECTIVES

Upon successful completion of this module, you will be able to:

- list five methods of reducing your exposure to electrical shock hazards and give examples of each
- describe approach distances applicable to cranes having circuits with less than 750 volts and to whom they apply
- define the two-man rule
- describe a generic policy on electrical shock
- list the five steps in responding to an electrical shock

ACCESS TO CRANES

Organizations should have policies and procedures in place to safely regulate personnel boarding cranes. No one should board a crane unless he or she has a true need to do so. This 'true need' can be defined as 'crane operations, maintenance, or management personnel who have been assigned to be on the crane for work related purposes.' With very few exceptions, no one else should ever have a need to be on a crane. Even if you are crane operations, maintenance or management person, you will need to have authorization to board a crane. This authorization may come in many different forms such as: supervisor assigned maintenance, inspection or test work, a work authorization document, accident investigations, engineering evaluations, and troubleshooting, to name a few. All personnel should obtain permission from crane operations management before boarding a secured crane, and, if boarding an operating crane, get permission from the crane operator. If an operating crane is currently involved in lifting operations, permission from the rigger-in-charge is also required. Inform all affected personnel of the purpose of you visit.

SITE EVALUATION

A site evaluation shall be performed by all repair personnel boarding the crane to determine any physical, mechanical or electrical hazards. In addition, qualified persons shall assess the need for, and methods of, preventing electrical shock. Lockout or tag-out shall be used when required as discussed in your training.

Additional personnel can be used to act as a guard, to accommodate the two-person rule, and to assist in communication.

Additional personnel protection equipment, such as electrical safety gloves, electrical safety mats, and electrical safety tools may be appropriate to use.

Work with a partner. Even when working on batteries or other low-voltage systems (50-150 Volts), work with a partner. If an accidental shock occurs, the partner's job is to be available to switch off the power source, immediately call for emergency personnel, and provide lifesaving techniques. This is known as the "Two Person Rule".

Two-Person Rule defined – The requirement [when invoked] for two qualified electrical workers to be present in the workplace and to be aware of the other worker's task while performing electrically hazardous work. Under the Two-Person Rule, *each worker must:*

- Be a qualified person (qualified electrical worker)
- Remain in visual and audible contact with the other worker(s) performing the work
- Have a thorough knowledge of the location and operation of disconnects and shut-down controls
- Have ready means to alert emergency-rescue personnel
- Be able to safely disengage an injured worker from the hazard
- Be trained and certified in CPR and AED and know the location of the nearest AED, except for work in battery Classes 4.2 and 4.3 below 100 V.

Additional administrative controls, such as danger tags and caution tags, may be appropriate to improve the electrical safety of the job or task.

Additional documentation, as required by your activity, may address local electrical safety concerns more adequately.

PREVENT ELECTRICAL SHOCK

Listed here are five methods that can be used to mitigate the risk of electric shock. They include:

1. de-energizing circuits [before beginning work]
2. adding resistance [in series with the body]
3. reducing the voltage levels
4. limiting current flow, and
5. grounding equipment or circuits

Described as follows…

MITIGATING ELECTRIC SHOCK - DE-ENERGIZE CIRCUITS

De-energize Circuits

First on the list of methods for mitigating electric shock is to de-energize the machine or equipment prior to beginning any work. Equipment is considered de-energized when the following four conditions are met.

1. All sources of electrical energy are identified through on-site investigation and review of systems and documentation.
2. All sources of electrical energy have been secured and placed in a safe condition.
3. All sources of electrical energy have suitable and properly installed electrical isolation devices along with locks and/or tags as required.
4. All exposed conductors and equipment to be serviced has been verified to be de-energized by properly performed voltage checks.

A local electrical safety policy that contains standards to prevent, preclude or otherwise minimize the possibility of working on energized circuits is an excellent step toward mitigating electric shock to personnel.

Exceptions

Live parts to which an employee may be exposed shall be de-energized before the employee works on or near them. This rule should always be followed. However, circumstances may exist that require an exception to this rule. De-energizing may not be required under the following conditions…

- if de-energizing equipment introduces additional hazards or is infeasible due to equipment design or operational limitations
- if safe administrative or engineering provisions have been promulgated for work to be performed in such a manner, or
- if live parts that operate at less than fifty volts to ground

…de-energizing may not be required.

Examples include: testing of electric circuits that can only be performed with the circuit energized; work on circuits that form an integral part of a continuous process that would otherwise require the entire piece of equipment to completely shut down; taking electrical measurements at test jacks or dead front-panel fuse holders; and when using insulated test leads.

Remember, only qualified persons may work on electric circuit parts or equipment that has not been de-energized. Such persons shall be capable of working safely on energized circuits and shall be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools. Electrical safe work practices shall always be used when working in areas with exposed energized components.

Mitigating Electric Shock - Add Resistance

Second on the list of methods for mitigating electric shock is to add resistance between the qualified person and the energy source. Of course, one of the best ways to do this is to maintain a safe approach distance between the worker and the live conductor. When this is not possible then electrical safety equipment shall be utilized. This includes rubber gloves, rubber arm sleeves, hard hats, rubber mats, and insulated tools. When it is impractical to cover the exposed body parts with electrical safety equipment, the exposed conductors shall be covered with non-conductive materials. Employees involved in this type of work should take steps to increase their resistance (or decrease their conductivity) by removing conductive items from their body such as metallic watch bands, bracelets, rings, key chains, necklaces, metallic aprons with conductive threads, metal head gear, belt buckles, and metal rimmed eyeglasses.

Note: All OSHA, NEC and local standards and policies regarding electrical safety shall be followed, including arc flash requirements.

Resistance – Approach Distances

Approach distances are those distances that workers must maintain between their unprotected body parts (or conductive objects they may be holding or working with) and exposed energized conductors. Approach distances can include spaces around energized conductors that are considered conductive regions.

Unprotected is defined as not using electrical safety equipment to protect exposed body parts.

Conductive is defined as an uninsulated tool or object that is not maintained electrically safe. Insulated objects are considered conductive if they do not have an appropriate insulating rating for the voltage involved.

Qualified persons and unqualified persons have different approach distances and boundaries.

Resistance – Electrical Safety Equipment (1)

Add Resistance

Electrical protective equipment, such as insulating blankets, matting, covers, line hose, insulated tools, gloves and sleeves, effectively add resistance in series with the body. It can greatly increase the safety of crane maintenance personnel working on or near exposed electrical conductors when used correctly for its intended purpose. To provide suitable protection from electric shock, electrical protective equipment shall be designed, manufactured, and rated for specific applications thus allowing employers and employees the ability to select the appropriate level of protection for the level of hazard present. Electrical protective equipment shall be periodically tested and maintained in a safe, reliable condition.

Care of…

To ensure your electrical protective equipment provides its intended level of protection, it must be maintained in a safe, reliable condition. It shall be stored in a container that will protect it from exposure to moisture and sunlight. It must be inspected before each use for evidence of damage and if found to be defective, replaced immediately. Electrical protective equipment shall be kept clean and dry at all times.

Rubber Gloves

One of the most exposed portions of an electrician's body is his or her hands. One of the most effective means of protecting exposed hands from electric shock is by the proper use of rubber insulating gloves. The following is provided as a guideline for proper use of rubber insulating gloves.

It is an accepted safe electrical work practice to use on hand to perform work on exposed energized electrical conductors. When it is not practical or possible to wear rubber insulated gloves on both hands, wear one glove on the working hand. If it is not practical or possible to wear the glove on the working hand, the glove should be worn on the non-working hand. If the location or conditions might cause sudden movement of the crane or equipment, rubber insulated gloves should be worn on both hands.

Rubber insulated gloves are protected from damage by wearing the provided leather outer gloves. These gloves are sized to fit over the rubber gloves and shall not be used for other purposes.

Although perspiration causes moisture to build up inside the rubber gloves, they will remain functional as long as the outside surface remains dry. Rubber insulated gloves should be cleaned and dried after each use and before storing them.

Note: As always, review local electrical safety policies and procedures for use of electrical protective equipment at your activity.

Rubber Sleeves

If a qualified worker must reach into or beyond an exposed energized electrical conductor or past the point of protection provided by rubber insulating gloves, he or she shall don rubber insulating sleeves to protect any exposed portions of the arm. Rubber insulating sleeves provide reliable protection when used correctly and shall not be used for other purposes. They must be used with rubber insulating gloves. The sleeves are donned first, followed by the gloves, ensuring no part of the arm is exposed.

Although perspiration causes moisture to build up inside the rubber sleeves, they will remain functional as long as the outside surface remains dry. Rubber insulated gloves should be cleaned and dried after each use and before storing them in their protective bag.

RESISTANCE – ELECTRICAL SAFETY EQUIPMENT (2)

Electrical Protective Safety Equipment – Hard Hats

Hard hats, which are designed to protect your head from falling objects, are a very important part of your personal protective equipment needs. However, if you are at risk of contacting energized electrical conductors with your head, then you must wear a hard hat that also protects you against electrical hazards. A hard hat meeting the requirements of *ANSI/ISEA Z89.1 2014* class G or E satisfies this requirement and will be labeled as such on the inside of the hat. Class G hard hats are intended to reduce the danger of contact with low voltage conductors. Class E hard hats are intended to reduce the danger of contact with high voltage conductors.

Read the Z89.1 standard for additional information.

Rubber Mats

Rubber insulating mats provide another alternative to adding resistance between the worker and the exposed energized electrical conductor. However, rubber insulating mats are the least desirable of insulating methods and should only be used if no better means of protections is suitable. The problem with using rubber insulating mats is that it triples the worker's exposure to electrical hazards. You see, a qualified person must first install the mat, thereby exposing himself to the hazard. Secondly, he must work in the vicinity of the hazard. And finally, he must remove the mat, exposing himself to the hazard a third time. Other, more suitable methods should be considered before using rubber mats. Rubber insulating mats shall not be used on wet metal decks or on the ground.

Note: Follow OSHA, NEC and local electrical safety policies when installing or removing electrical matting.

Insulated Tools

When working near exposed energized conductors or circuit parts, each employee shall use insulated tools if the tools might make contact with such conductor or parts. Insulated tools that are designed, manufactured and rated for energized electrical work provide and effective safeguard against electric shock, when used correctly. It must be pointed out that standard tools with plastic handles or coatings, should not be used on energized electrical conductors. Only insulated tools rated for electrical work shall be used on or near energized electrical parts. Insulated tools shall be periodically inspected for damage that may degrade their resistance. They shall be kept clean and dry. They shall be stored properly. The use of insulated tools does not preclude or exclude approach distance requirements.

Other Gear

In addition to the electrical safety gear just discussed, there are many other safety considerations and equipment that may be suitable, or even required, for certain electrical work situations.

Non-conductive wood or fiberglass ladders should be used for electrical work.

Power tools used around exposed energized electrical conductors, shall be rated “double-insulated”, have nonconductive bodies, and be powered through a ground fault interrupter.

Full face shields shall be used when working around high voltage, lead-acid batteries, and large capacitors or exposed energized electrical conductors where the possibility of dropping a tool exists.

Snug fitting cotton, non-synthetic, low combustion clothing, should be worn to reduce exposure to electrical, mechanical and fire hazards.

Only electrical safety rubber boots provide adequate protection in wet and dirty locations.

Electrically safe shoes, even though they have no conductive eyes, shanks, or toe guards, provide little insulation if not kept clean and dry.

Note: For more information, refer to NFPA 70E article 130.6-7 and local policy for additional arc flash requirements regarding clothing and gear which may or may not be worn.

Mitigating Electric Shock 3 – Decrease Voltage

Third on the list of methods for mitigating electric shock is to decrease the voltage. This method is more of a design or "engineered-in" approach to mitigating electric shock. Although modern design features on cranes have reduced many potential voltage and current outputs, this method offers very few additional benefits for workers performing maintenance.

Mitigating Electric Shock 4 – Limit Current

Fourth on the list of methods for mitigating electric shock is to limit the current. Current limiting devices are installed in circuits that have a higher than normal potential for exposing personnel to electric shock. Ground fault interrupters, commonly called GFIs, will not prevent electric shock but are designed to minimize the duration of the shock, if any, as well as the amount of current present. Common GFIs are set to trip at approximately 5 milliamps and can de-energize a circuit in a fraction of a second. Caution must still be exercised when working on circuits with GFIs installed because this "fraction-of-a-second" delay is still enough time to receive an electric shock.

Ground fault circuit interrupters or GFCIs and equipment protection devices, or EPDs, should not be confused with GFIs. GFCIs and EPDs operate at higher currents, as much as 30 milliamps, which can result in a severe and potentially lethal electric shock.

Mitigating Electric Shock 5 –Equipment Grounding

The fifth method for mitigating electrical shock is equipment grounding. Proper grounding per article 250 and article 610 of the NEC is essential for personnel safety on cranes and hoists. Equipment grounds provide a low resistance path for any fault current. Should a fault occur, workers in contact with the conductive parts of the equipment enclosure, while still exposed, have a substantially reduced chance of electrical shock. A crane or hoist’s grounding system, if installed correctly, provides both personnel protection and a low-impedance path back to the source, so that the over current devices already installed as part of the controller configuration, can operate quickly, in case of a fault.

General Electrical Safety Requirements (1)

General Electrical Safety Requirements

Some additional electrical safety concerns that need to be mentioned include:

- clearances in and around electrical panels
- the use of electrical cables and extension cords
- working in wet locations
- working with damaged tools
- working on damage equipment

Panels

The space in front of and around any electrical panel can impact the safety of personnel who work on or in those panels. A working space, or access, in front of each electrical panel shall be maintained at all times. On cranes, the dimension of the working space in the direction of access to live parts that are likely to require examination, adjustment, servicing, or maintenance while energized shall be a minimum of two and a half feet. Where controls are enclosed in cabinets, the door(s) shall either open at least 90 degrees or be removable. Reference 29 CFR 1910.306(b)(4) and NEC Article 610.57

Note: NEC 2017 Article 110 Part II, Table 110.26(A)(1) requires clearances of 3-5 feet (depending on conditions) for non-crane installations.

Cables

Good housekeeping at any worksite is always an important part of maintaining a safe work environment. Electrical cables can be a trip or even a shock hazard if left on floors, decks and other walking areas. They should, wherever possible, be kept off floors, decks and out of passageways. It is very important to avoid damage to the cables and eliminate tripping hazards to personnel.

Cords

Extension cords can be used for many different types of industrial applications. They shall be correctly sized, rated, be of three-wire type construction, designed for hard or extra-hard usage, and only used for approved and designated purposes. Extension cords shall not be a substitute for permanent or fixed wiring and shall not be run on the floor or deck. They shall not be fastened with staples, hung from nails, or suspended by wire. A void running extension cords through doorways, windows or holes, unless approved policies and protection are provided. Extension cords shall not be installed in raceways nor spliced. Extension cords shall be removed immediately when no longer needed.

As always, check local activity electrical safety policies and procedures for approved usage of extension cords.

Wet Locations

Working in wet locations raises additional safety concerns regarding electrical shock. Portable electrical tools in wet locations must be suitably designed for wet service and clearly labeled with this information. They must be inspected by the user for damage prior to each shift that they are used. Also, electrical tools are to be protected by a ground fault circuit interrupter (GFCI) and tested each shift prior to use.

GENERAL ELECTRICAL SAFETY REQUIREMENTS (2)

Damaged Electrical Tools

Any damaged or malfunctioning portable electrical tool shall be taken out of service, tagged and/or clearly labeled immediately and returned to tool room for repair or disposal, as applicable.

Working on Damaged Equipment

“Damaged electrical equipment can be extremely dangerous and must be approached with caution using a carefully prepared plan.”

Although this NAVOSH quote is general in nature, it applies particularly well to crane maintenance workers who have been sent to a crane to troubleshoot a reported problem.

Unknown equipment failures on cranes can result in improper and unexpected equipment movements and operations. Other unknown conditions such as mechanical and electrical hazards may exist. It is important to exercise extreme caution until the full extent of the failure has been determined.

Exposed Conductors

The risk of electrical shock is minimal, when there are no exposed energized conductors. Whenever possible, do not work in electrical panels or equipment with exposed energized components. Energized electrical conductors are not considered to be exposed if they are properly manufactured using insulating material appropriate for the application and rated for the expected voltage. Also, they must be adequately recessed to prevent inadvertent contact. This includes being constructed in such a manor to allow the non-conductive parts to protect the conductors. They must be installed and guarded in such a manner so that contact with the conductors is unlikely.

OSHA Definitions

OSHA: *"…a significant risk exists, when working on equipment that is adjacent to exposed energized conductors…"*

Conductive surfaces are defined as any object that is not specifically insulated for electrical voltage. Examples are masonry, concrete, wood, tile, carpeting and metal. These surfaces shall be considered conductive until they have non-conductive protection in place.

Non-conductive surfaces are defined as being specifically designed and designated for electrical insulation. Examples are rubber insulating matting, rubber insulating gloves, rubber insulated electrical tools, work benches and coverings. These surfaces must undamaged and remain free of oil, grease, and liquids, etc.

Work Team

When working on or near energized circuits, it's best to work as a team. At least two people must be present. The first person, an electrically qualified person, will perform the job – we'll call him the worker. The second person, the safety person, must be CPR qualified and may not be involved in any work. The safety person must remain in visual contact with worker and know how to secure power. A third person is required if working in remote areas, to provide clear radio communications and to summon help if necessary.

While this screen describes a good work practice, local policies and procedures shall be followed.

Additional OSHA Requirements

Additional requirements exist to govern situations where a loss of control, near miss, or unexpected electrical hazard occurs. First, you must report all situations to the nearest supervisor. Next, you should warn others, and stay clear and remain clear of any electrical hazard to avoid possible injury. Guard the area to assure that additional personnel arriving are aware of the hazard. Finally, all persons must observe approach distance requirements. Situations where the potential for electrical shock exists but is not expected and where the source of the electrical potential is not properly controlled, are considered "near misses" and shall be reported to your supervisor.

Leaving the Work Site

If you find that you need to leave the electrical work site while the equipment is in an out-of-normal condition, you must take precautions as necessary to assure the safety of others. This should be in the form of additional safeguards and/or administrative controls.

Out-of-Normal Equipment

Out-of-Normal Equipment

Out-of-normal equipment is not fully intact, not assembled and would create an electrical hazard if energized. During repair and maintenance, partial disassembly of electrical equipment is to be expected. When left in an out-of-normal condition for extended periods, positive actions need to be taken to avoid creating electrical hazards or inadvertently energizing exposed electrical components.

Positive Actions

When electrical equipment is in an out-of-normal condition, positive actions must be taken to address the additional hazards, both to the people working on the equipment, and other people in the area. Some examples of positive actions include: physically disconnecting the power supply leads at the power source; insulating the disconnected leads with suitable electrical sleeves, rated for the voltage of the circuit; providing a temporary enclosure or shield; and lockout/tagout of energy sources.

Electrical Shock

An electrical shock has occurred if a person can feel the shock, a person is observed reacting to what could be a shock or when tools or equipment indicate a shock has occurred.

Response to Electrical Shock

Electrical Shock Policy

The following plan provides a good policy for all electrical shock accidents or incidents.

1. Turn off the power
2. Call 911, or your local emergency phone number
3. Sit or lie down
4. Apply CPR
5. Preserve the scene

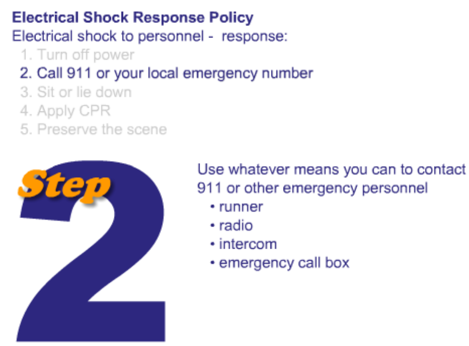
More details for each of these will be discussed in the following screens.

1. Turn Off Power

The first step during an electrical shock accident or incident is to turn off the power. Use breakers, switches, disconnects or unplug cords to secure power. If a person is seen being shocked, do not touch the victim yourself until the victim is clear of the electrical source. The best chance the victim has of surviving the shock is with your assistance. Risking electrocution yourself is not good judgment.

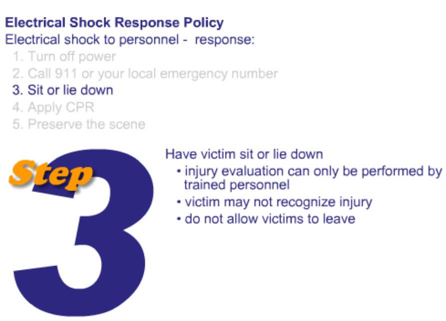
2. Call 911

The second step is to call for help. Call 911 or your local emergency phone number or have someone else call. Use whatever means available to get emergency help: runner, radio, intercom, call box, etc.



3. Victim Position

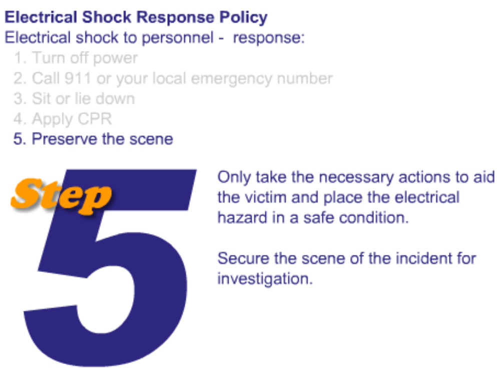
The third step is to get the victim to sit or lie down and stay immobile. Only medical personnel can determine the extent of injuries, treatment or evacuation method. Also, victims cannot be expected to use good judgment. Expect that they may want to ignore the accident and/or attempt to exit the crane. Make every attempt to persuade the victim that this is not a good choice and that it may be dangerous.



Finally, victims cannot adequately assess their own injuries. Other victims of electrical shocks have died hours after the accident due to internal injuries that went untreated.

4. Apply CPR

The fourth step is to provide cardiopulmonary resuscitation or CPR, only if you are qualified and if the victim isn't breathing or doesn't have a pulse.



5. Preserve the Scene

Step five is to preserve the scene where the shock occurred to the maximum extent possible until command authorities release it. Take only those actions necessary to secure the power, make the victim safe, and call for help and effect evacuation.

Finally, when directed by supervision or higher authority, make the crane safe and secure the crane.

Review and Summary

In Electrical Safety, Module 3, Practical Application, you learned five methods for reducing your exposure to electrical shock hazards. You can describe approach distances applicable to cranes having circuits with less than 750 volts and to whom they apply. You can define the two-man rule, and describe a generic policy on electrical shock. Finally, you can list five steps in responding to an electrical shock.

NOTES

Electrical Safety Module 3 Knowledge Check

Online questions may appear in a different order that those shown below.

1. True or False

To board a crane, personnel must have authorization and a true need to do so.

A: True
B. False

2. Select the best answer.

Upon boarding a crane, service personnel shall perform a site evaluation to determine _____ hazards.

A: physical
B. mechanical
C. electrical
D. all listed items are correct

3. Select all that apply.

Select the methods that can be used to mitigate the potential of electric shock.

A. limit current
B. reduce voltage levels
C. add resistance
D. de-energize circuits
E. review documentation
F. ground equipment

4. Select the best answer.

Equipment is considered de-energized when the following condition(s) has/have been met…

A. All sources of electrical energy are identified through on-site investigation and review of systems and documentation.
B. All sources of electrical energy have been secured and placed in a safe condition.
C. All sources of electrical energy have suitable and properly installed electrical isolation devices along with locks and/or tags as required.
D. All exposed conductors and equipment to be serviced have been verified to be de-energized by proper performed voltage checks.
E. B and C
F. All listed items are correct.

5. True or False

Approach distances are those distances that workers must occupy between their unprotected body parts and exposed energized conductors.

A: True
B. False

6. Select the best answer.
What is the minimum approach distance for qualified workers exposed to conductors energized between 50 volts and 300 volts?

A. avoid contact
B. 1 foot
C. 2 feet 2 inches
D. 3 feet 9 inches

7. Select all that apply.
To ensure your electrical protective equipment provides its intended level of protection, it must be maintained in a safe, reliable condition. This includes:

A. keeping it clean and dry at all times
B. storing it in a container to protect it from exposure to moisture and sunlight
C. inspecting it before each use for evidence of damage
D. all listed items are correct
E. applying lube to rubber parts

8. True or False
Standard tools with plastic handles or coatings are acceptable for use on energized electrical conductors.

A: True
B. False

9. Select the best answer.
When working near exposed energized conductors or circuit parts, each employee shall use insulated tools, if the tools might make contact with such conductor or parts. Insulated tools must be _____, _____, and _____ for energized electrical work. When used correctly, insulated tools will provide an effective safeguard against electric shock.

A. sorted, shaped, selected
B. designed, manufactured, rated
C. gauged, guarded, grounded
D. tested, tagged, tuned

10. Select the best answer.
On cranes, the dimension of the working space, in front of an electrical panel, in the direction of access to live parts that are likely to require examination, adjustment, servicing, or maintenance while energized shall be a minimum of _____.

A: 24 inches
B. 30 inches
C. 36 inches
D. 48 inches

11. True or False
Extension cords are and acceptable substitute or permanent of fixed wiring.

A: True
B. False

12. Select the best answer.
Work with a partner. Even when working on batteries or other low voltage systems (50-150 volts), you should work with a partner. If an accidental shock occurs, the partner's job is to be available to switch off the power source, immediately call for emergency personnel, and provide lifesaving techniques. This is known as the _____.

A. Two Person Rule
B. Rule for Electrical Work
C. Common Sense Rule
D. Rule of Duplicity

13. Select the best answer.
A shock has occurred if...

A: a person can feel a shock
B. a person is observed reacting to what could be a shock
C. when tools or equipment indicate a shock has occurred
D. all the listed items are correct

14. Select the best answer.
While working on the crane, you observe a fellow mechanic receive a shock. Which of the following items is not part of a good electrical shock response policy?

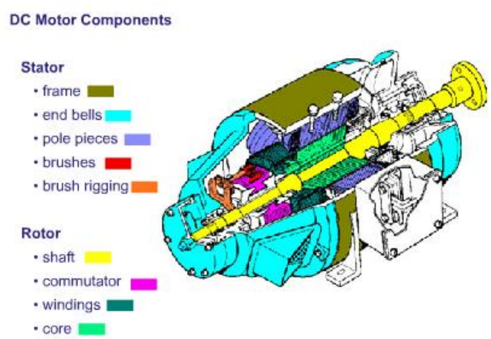
A: leave the crane immediately
B. secure poser
C. call emergency response personnel
D. provide first aid/R as needed
E. have victim sit or lie down

DC MOTORS

Learning Objectives

Upon successful completion of this module, you will be able to

- list the basic parts, components, and assemblies that make up a DC motor
- discuss four basic types of DC motors including series wound, shunt wound, compound wound, and permanent magnet
- describe how electromagnetic force and counter-electromagnetic force work together to create effective armature voltages…and…
- explain the general inspection, test and maintenance procedures for DC motors



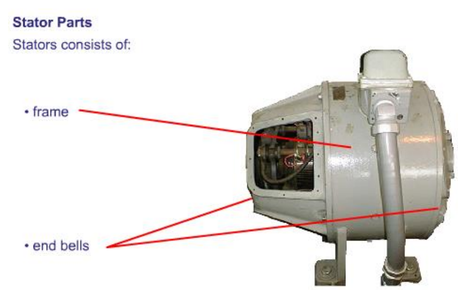
DC Motor Components

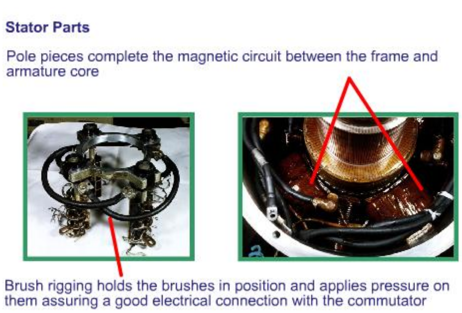
DC Motor Components

The basic components of a typical DC motor are the stator and the rotor. The stator, or yoke, consists of a frame, end bells, bearings, pole pieces, and brushes. The rotor, or armature, consists of a shaft, a commutator, the windings and the core.

Stator Parts (1)

The stator is constructed of a steel or iron frame that is normally circular in shape. The end bells consist of end plates which are fastened to each end of the frame. These end plates support the bearings which in-turn support the armature shaft. The bearings and end bells serve to keep the armature shaft properly positioned within the motor and with respect to the other components.



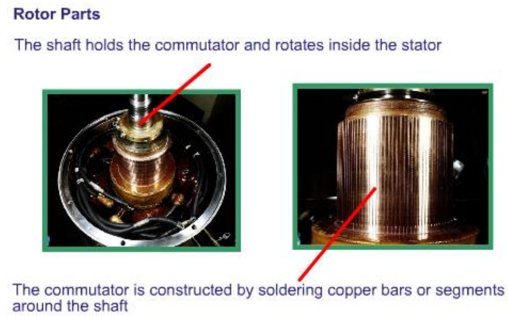


Stator Parts (2)

The stator also contains brushes, brush rigging, and pole pieces. Brushes, and their rigging, are mounted either to a yoke or directly to the end bell. Brush rigging, as the name implies, supports the brushes and keeps them in the proper position in relation to the commutator. The brush tension springs, which are part of the brush rigging, maintain pressure on the brushes to assure proper contact with the commutator. Pole pieces support the field windings and complete the magnetic circuit between the frame and the armature core. Pole pieces are made of iron and are either solid or an assembly of thin strips called laminations.

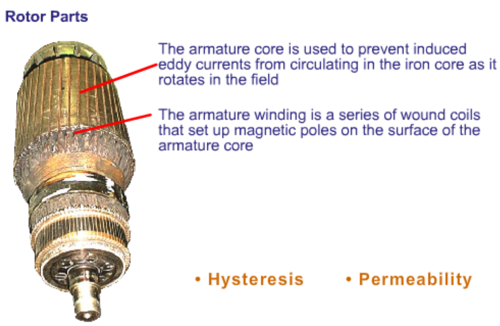
Rotor Parts (1)

The rotor contains a commutator, which is constructed by placing copper bars in a cylindrical form around a shaft. The copper bars are soldered in place, adjacent to the coils, and are insulated from each other and the shaft.



Rotor Parts (2)

Other parts of the rotor include the armature core and armature winding. The armature core is made of laminated iron pressed tightly together. The laminated construction is used to prevent induced eddy currents from circulating in the iron core as it rotates in the field. The laminations have little effect on hysteresis losses in the armature windings as compared to the effects of permeability in the core materials. The armature winding is a series of coils wound in the armature slots, and the ends of the coils connect to the commutator bars. The purpose of the armature winding is to set up magnetic poles on the surface of the armature core.



Hysteresis: the lagging of an effect behind its cause, as when the change in magnetism of a body lags behind changes in the magnetic field.

Permeability: a measure of the change in magnetic induction produced when a magnetic material replaces air, expressed as a coefficient or a set of coefficients that multiply the components of magnetic intensity to give the components of magnetic induction

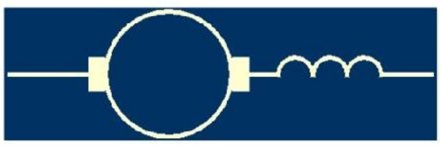
DC Motor Types

DC Motor Types

The four major DC motor types are series wound, shunt wound, compound wound and permanent magnet. Let's take a quick look at each of the motors.

Series Wound

In a series wound motor, the field is made up of a few turns of heavy wire around the pole pieces. All the motor current passes through the armature and field windings in series. Series wound motors have poor speed regulation and is explained as follows:



As the field is strengthened by increased current, the motor speed decreases. Conversely, as the load is decreased, the field is weakened, and speed increases, and at very light loads, speed may become excessive. For this reason, series-wound motors are usually directly connected or geared to the load to prevent runaway.

The increase in armature current with an increasing load produces increased torque, so that the series-wound motor is particularly suited to heavy starting duty and where severe overloads may be expected.

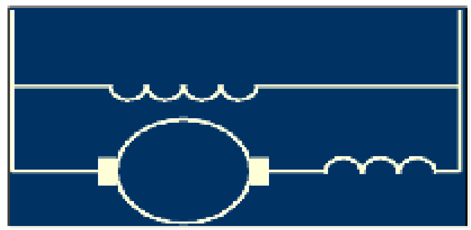
Shunt Wound

The shunt wound motor is one in which the field is wound with thousands of turns of fine wire, and connected in parallel with the armature. In this type of motor, the field current is independent from the armature current and the strength of the field in not affected appreciably by change in the load. This provides relatively good speed regulation regardless of the load and is beneficial when overhauling cannot be tolerated.

This type of motor has poor starting torque and should be used for the operation of machines requiring an approximate constant speed and that can tolerate low starting torque and light overload restrictions/characteristics.

Compound Wound

Another type of DC motor is the compound wound motor. Both shunt fields and series fields are wound around the same pole pieces. The series and shunt fields are connected as shown in this illustration with respect to the armature. Compound wound motors have some of the characteristics of both series wound and shunt wound motors according to the amount of field provided by each winding. The compound wound motor is normally used for loads requiring relatively constant speed but having frequent peaks needing high torque and for occasions when the motor may run unloaded. There are four possible ways to configure a compound motor:



- long-shunt cumulative
- shot-shunt cumulative
- long-shunt differential
- short-shunt differential

Because the short shunt provides no advantage and differential compounding is seldom used, the most common configuration of compound wound DC motor is the long shunt cumulative.

Permanent Magnet

The final DC motor is the permanent magnet type. Permanent magnets are mounted in an iron shell so that one is north and one is south with respect to the armature. The magnetic lines of force go from the north pole through the armature to the south pole and then return to the north pole through the iron shell. The armature is the electromagnet. The coils of the armature are soldered to segments of the commutator. These segments act as a sliding switch, to switch the current from the line to certain windings of the armature. The brushes, which are the other side of the sliding switch, carry the current from the line to the commutator segments. They are stationary and positioned so that they will energize the coils of the armature in such a way that they create poles. As the armature turns, the position of these poles in relation to the brushes does not change.

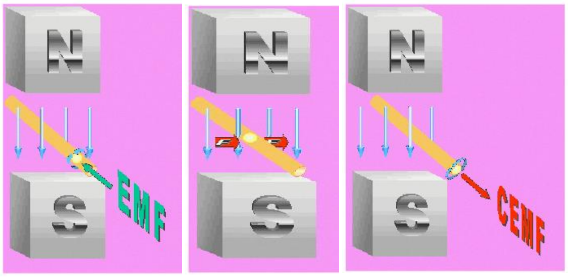
Electromotive Forces

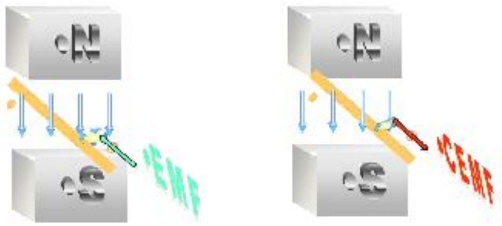
Electromotive Forces

Now we will explain electromotive and counter electromotive force. Electromotive force, or EMF, causes electrons to move. It is the reaction of electrons when like charges repel each other and opposite charges attract. When electrons are moved away from their equilibrium, energy is stored in their charged fields. If given a path, these electrons will move to re-establish equilibrium. This ability to store energy in electrons, and the potential those electrons have of doing work is called voltage. When electrons move as a result of voltage, it's called current.

Electrons in motion produce a magnetic field about those electrons. When those magnetic fields react with other magnetic fields, forces are generated that tend to change the course of the electrons and/or cause the conductor to move. This reaction, which is the underlying principle of electric motors, converts electrical energy into mechanical energy.

As soon as the conductor moves, lines of force from the fields are cut by that conductor. This action produces fields, which encircle the conductor producing a voltage in the opposite direction, which is termed counter electromotive force, or CEMF.





EMF Electromotive Force CEMF Counter

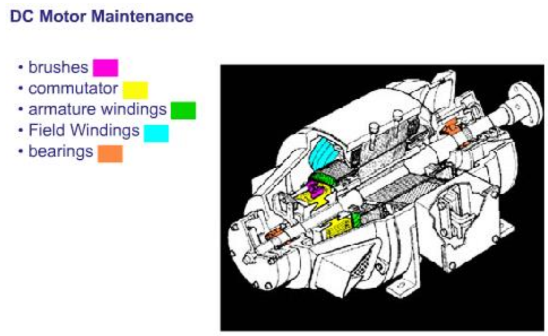
EMF and CEMF are the forces that influence armature current. EMF and CEMF have opposite polarities. The result of adding these two forces in opposite directions is the effective armature voltage. As the armature turns faster, more CEMF is generated, thus reducing the effective armature voltage and armature current.

Armature current is proportional to the motor torque. As speed increases, torque decreases until it is equal to the torque demand on the motor shaft. Equilibrium speed is reached and remains constant until some parameter changes.

DC MOTOR MAINTENANCE (1)

DC Motor Maintenance

Components and parts begin to degrade as soon as they are placed in service. To prevent premature failure, maintenance will need to be performed. Periodic inspection and maintenance can extend the life of many parts and motors and reduce breakdowns and failures. The five areas of DC motor maintenance are:

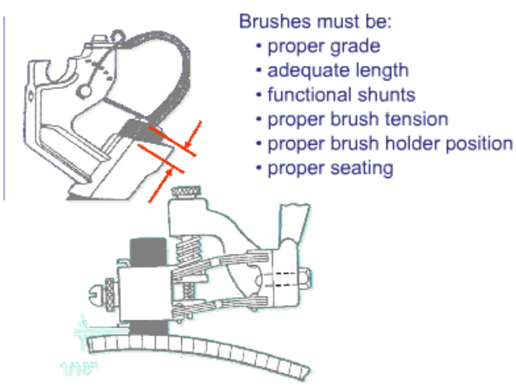


- brushes
- commutator
- armature windings
- field windings
- bearings

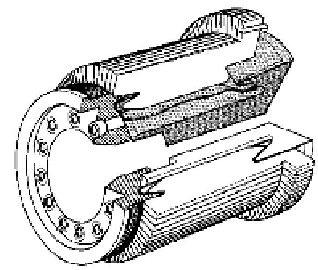
Coordinate the colors to identify the maintenance areas.

Brush Maintenance

Brushes are the consumable component of DC motors. Shown here is a diagram of a typical brush assembly. Brushes must be of the proper grade, based on material and hardness, and as recommended by the manufacturer. They must be long enough to provide adequate brush material to accommodate the predicted wear for one maintenance period. Their shunts, the flexible conductor that completes the electrical connection between the brush and the brush holder, must be in good electrical condition. The brush tensioning device must provide the correct pressure for the brush used. The brush holder must be positioned correctly to provide adequate support of the brush which is usually to be about one sixteenth of an inch above the commutator unless otherwise specified by OEM or local engineering instructions. Finally, the brush must be properly seated. The surface of the brush next to the commutator must be smooth, without chipped edges and without imbedded impurities.



Commutator Maintenance



The commutator is a vital part or every DC motor. How well the motor performs depends largely on how well the commutator is maintained. A commutator cannot function correctly unless the brushes make proper electrical contact (which should not be confused with physical contact). A properly functioning commutator has a conductive film and the brushes fit that film exactly. When normal current flows, a layer of electrons form a plasma field between the brush and the commutator and the brush is no longer in physical contact with the commutator. For the film and plasma field to form, a smooth cylindrical surface that runs true to center is required. To maintain a commutator properly you must be able to recognize faulty conditions and prevent or correct them.

Commutator Film

The first step in maintaining a commutator is assuring the proper surface film. The motor manufacturer selects the proper brush grade depending on the application of the motor. A surface film of carbon, graphite, copper oxide, and water vapor is deposited on the commutator by the electrochemical action of the brushes and commutator as the motor operates. The film is affected by many factors, e.g., temperature, atmosphere, grade of brush, humidity, chemical contamination, abrasive dust, oil vapors and many other materials. Colors from dark brown to old copper are not unusual provided the surface is smooth and polished, however, a new shiny copper finish is not desirable. The surface should look like an old penny and not be disturbed. The development of a color pattern on the commutator bars is not a concern as long as the pattern is uniform around the entire commutator.

Causes of Commutator Damage

Nothing needs to be done to the commutator unless damage exists. Possible causes of commutator damage are:

- excessive current load on the brush
- neutral plane out of adjustment
- wrong brush grade
- rough commutator surface
- contaminated atmosphere
- incorrect brush tension
- incorrect brush holder position

DC MOTOR MAINTENANCE (2)

Winding Maintenance

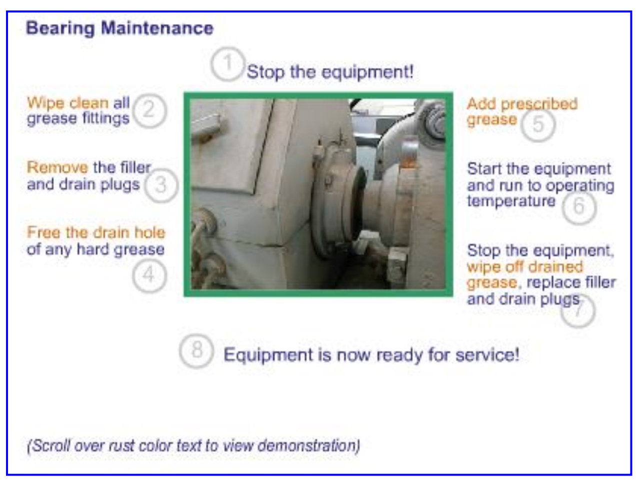
The maintenance concerns for the windings deals mostly with evaluation. Meggering is a resistive check made on all windings. A megger check consists of isolating the windings by disconnecting as needed, connecting a megger to the winding and to ground, and taking the reading. In general, acceptable megger readings of 20 mega-ohms for new or rewound windings, 10 mega-ohms for repaired windings, or 2 mega-ohms for working motors are no cause for concern. Your local engineering authority may choose to set other criteria. Low megger reading of less than 2 mega-ohms should be monitored. Readings that rise and fall with temperature and humidity indicate the insulation is not breaking down and are not of concern. Readings that continue to drop over time indicate the insulation is breaking down. Your local engineering authority shall evaluate the megger readings for trends to determine when the winding shall be removed, rewound, reinsulated, or replaced. Cleaning involves wiping down the exposed areas. The use of compressed air or solvents is more likely to worsen the condition than improve it.

Bearing Maintenance

Minimal lubrication is usually sufficient. Over lubrication that forces grease into the motor windings can be more detrimental than under lubrication. Check with your local activity engineering organization for approved and acceptable lubrication procedures.

The following is a basic bearing lubrication process.

- *stop operation of the equipment* ①
- *perform lockout procedure*
- *wipe all grease fittings clean* ②
- *remove drain plugs* ③
- *free the drain plug of any hardened grease* ④
- *wipe the area around the drain clean*
- *add OEM or engineering specified amount and type of grease* ⑤
- *remove lockout device*
- *restart the equipment*
- *run motor to operating temperature* ⑥
- *stop the motor*
- *wipe the drain plug and filler fitting clean, re-install plugs* ⑦
- *inspect for spilled grease and clean the work site*



Equipment is ready for service. ⑧

SUMMARY AND REVIEW

During this presentation on DC motors, you learned about the basic parts, components, and assemblies that make up a DC motor. We listed and discussed four basic types of DC motors including series wound, shunt wound, compound wound, and permanent magnet. You learned how EMF and CEMF work together to create effective armature voltages. Lastly, we discussed general inspecting, testing and maintenance procedures for DC motors.

NOTES

DC Motors Knowledge Check

Online questions may appear in a different order that those shown below.

1. Select all that apply.

What are the basic components of a DC motor?

A. intake
B., stator
C. crankshaft
D. rotor

2. Select the best answer.

What stator part supports the field winding and completes the magnetic circuit between the frame and the armature core?

A. commutators
B. end plates
C. brush rigging
D. pole pieces

3. Select the best answer.

What stator part supports the brushes and keeps them in the proper position in relation to the commutator?

A. end plates
B. commutators
C. brush rigging
D. pole pieces

4. Select the best answer.

What rotor part contains a series of coils wound in the armature slots with the ends of the coils connect to the commutator bars?

A: armature core
B. armature shaft
C. commutator bars
D. armature windings

5. Select the best answer.

What rotor part is constructed by placing metallic segments in a cylindrical form around a shaft?

A: armature shaft
B. armature
C. armature core
D. commutator

6. Select all that apply.
Which of the following items is not one of the four major types of DC motors?

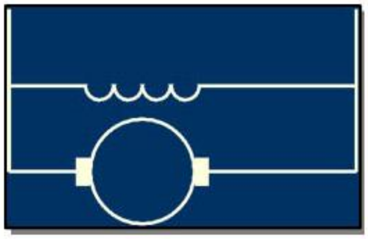
A. series wound
B. parallel wound
C. shunt wound
D. compound wound
E. permanent magnet

7. Select the best answer.
Select the item that correctly identifies the motor represented in the schematic.

A. permanent magnet
B. compound wound
C. parallel wound
D. series wound
E. shunt wound

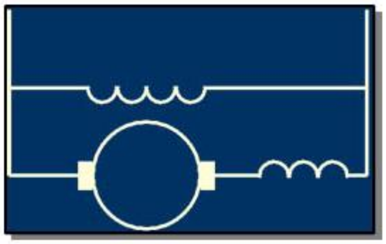
8. Select the best answer.
Select the item that correctly identifies the motor represented in the schematic.

A. compound wound
B. series wound
C. permanent magnet
D. shunt wound
E. parallel wound



9. Select the best answer.
Select the item that correctly identifies the motor represented in the schematic.

A. shunt wound
B. series wound
C. parallel wound
D. compound wound
E. permanent magnet



10. Select the best answer.
Select the item that correctly identifies the motor represented in the schematic.

A. series wound
B. shunt wound
C. parallel wound
D. permanent magnet
E. compound wound

11. Select all that apply.
From the list below, select those items that are primary concerns for DC motor maintenance.

A. shunts
B. commutators
C. field windings
D. bearings
E. armature windings
F. brushes

12. True or False
Brushes must be long enough to provide adequate brush material to accommodate the predicted wear for one maintenance period.

A. True
B. False

13. True or False
The brush holder must be positioned correctly to provide adequate support of the brush which is usually about one half inch above the commutator unless otherwise specified by OEM or local engineering instructions.

A. True
B. False

14. True or False
Brushes must maintain physical contact with the commutator at all times for proper operation.

A: True
B. False

15. True or False
Megger reading on windings that rise and fall with temperature and humidity indicate the insulation is not breaking down and are not of concern.

A. True
B. False

16. Select the best answer.
You are performing bearing maintenance on a DC motor as described in the basic lubrication procedure discussed in the DC Motors lesson. After adding the correct type and amount of grease to the motor bearing grease fitting, how long do you run the motor?

A. 30 minutes
B. until normal operating temperature is reached
C. the motor doesn’t need to be run
D. 10-15 minutes

DC GENERATORS

LEARNING OBJECTIVES

Upon successful completion of this module, you will have been exposed to basic DC generator theory. You should be able to:

- describe general construction of a generator including the major parts, components, and assemblies
- to list and discuss the operational differences between series, shunt and compound generators
- list and discuss several acceptable and unacceptable conditions often encountered in DC generator maintenance
- identify these conditions as well as how to troubleshoot and repair them

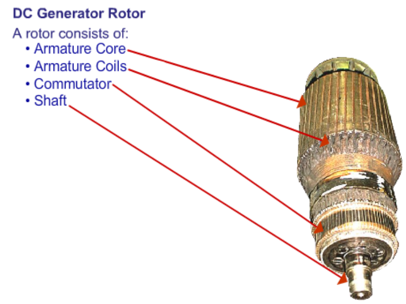
DC GENERATOR OPERATION

A generator converts mechanical energy into electrical energy through the principle of magnetic induction. Magnetic induction is the process of inducing current in a conductor by moving it through magnetic lines of force or by moving the magnetic lines of force over the conductor. In a generator, the coils in the armature are rotated through the magnetic fields. The field poles provide the magnetic fields which induce current in the armature. Field strength depends on the number of turns in the field coils, how much current flows in the fields, and how close the field is to the conductor. Output voltage is dependent on the number of turns per armature coil, the field strength of the magnetic field, the angle the coil cuts the magnetic field, and the speed of the armature.

VOLTAGE GENERATION

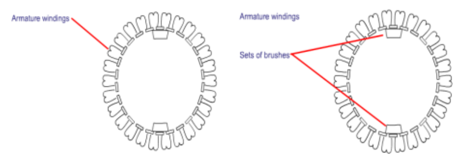
The armature in a generator is the rotating member that passes through alternating magnetic fields. This creates, or generates, an alternating current. As the coil is moving through one magnetic field, it produces a voltage in one direction. As it moves into the next field, the opposite voltage will be induced. Commutation is the process of conducting the current to the load before the voltage switches direction. The neutral plane is the point when an armature coil is not affected by the magnetic field of a field pole. At this point, there is no voltage induced in this armature coil. The brushes should be set to short circuit this coil when it is in the neutral plane.

DC Generator Rotor

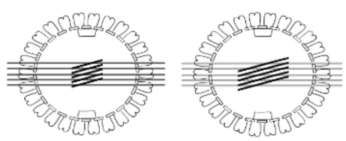


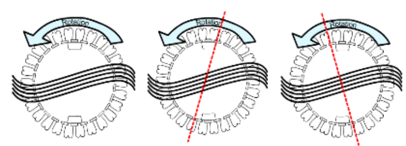
The basic components of a DC generator are the rotor and the stator. Shown here is a rotor. The rotor contains the armature core and coils, the commutator, and the shaft. The armature core is made up of iron or mild steel discs, called laminations, which are mounted on the shaft. These laminations are insulated from each other to prevent eddy current from flowing in the armature. The armature coils are wound into slots on the armature core. The commutator, made of insulated copper strips or segments, is connected to the armature coils. The shaft, and its associated bearings, support the core, coils, and commutator, and provides an axial plane on which to rotate.

Armature



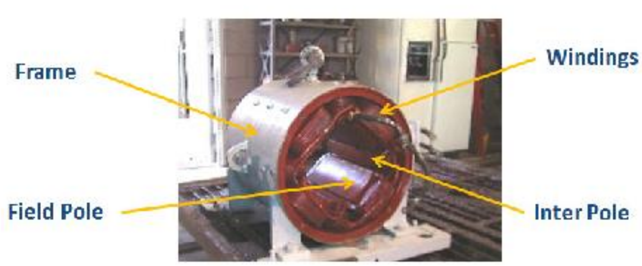
This illustration and animation shows how the armature circuits in DC generators are formed. First, the armature windings, which are loops of large wire generate the output voltage. The output voltage of a generator is determined by the amount of voltage generated per armature coil multiplied by the number of coils connected in series. Next, a four-pole generator with four sets of brushes and the same amount of coils connected in series will have the same output voltage and twice the available output current. Next, the armature reaction is caused by the field around the armature winding conductors. This same field distorts or pushes the lines of field flux in the direction of rotation and finally moves the neutral plane in the direction of rotation.



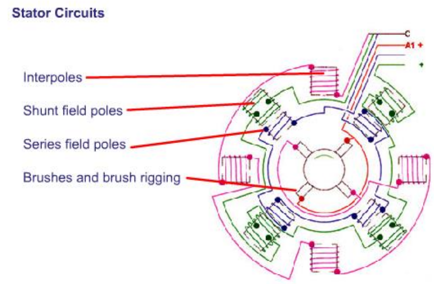


DC Generator Stator

The basic parts of the stator are the frame, poles, brushes, and windings. The frame serves as the support for the generator and forms part of the magnetic circuit. The field poles consist of windings and cores and are attached to the frame. Filed poles are laminated and insulated to prevent eddy currents. The interpoles are like small field poles. The stator also contains field windings mounted on the core.



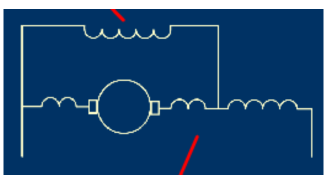
STATOR CIRCUITS



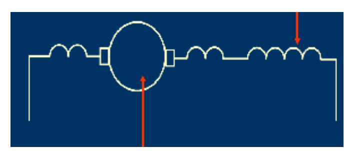
Stator circuits include interpoles, shunt and series field poles; and brushes and brush rigging. First, interpoles are small poles placed between the main field poles. They are wound of a few turns of large wire and are connected in series with the armature. The magnetic polarity is the same as the field pole following it in the direction of rotation. The magnetic field produced by the interpole increases as the armature current increases. The increasing magnetic fields from the interpole cancel the effects of self-induced currents and armature reaction. In effect, they move the neutral plane back to its original position.

OUTPUT VOLTAGE REGULATION

The shunt field sets the basic output of the generator. It is made up of many turns of small wire and is connected in parallel with the armature. A rheostat or a voltage regulator connected in series with the shunt field controls the voltage and current levels. The current level controls the strength of the magnetic fields in the generator. The series field aids the shunt field by regulating the output voltage. The series field is wound with few turns of large wire and is connected in series with the armature. It is mounted on the same core as the shunt field and has the same magnetic polarity. As armature current increases, the current and magnetic field in the series field increase and aid the shunt field.

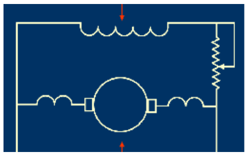


SERIES DC GENERATOR



There are three basic types of DC generators. They are the series (shown in this illustration); the shunt, and the compound.

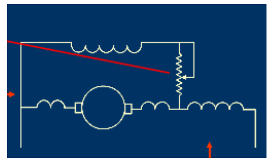
First, in the series generator, the field is connected in series with the armature so the current is the same in both. As load current increases the amperage in the series field and the magnetic field increase. This causes an increase in output voltage.



Shunt DC Generator

In the shunt DC generator (shown here) the field is connected in parallel with the armature. The current in the field is constant because the magnetic field strength is constant regardless of load. As the load current increases, the amount of voltage dropped across the resistance in the armature increases causing a corresponding decrease in the voltage and current in the shunt field. As the load current increases the output voltage decreases slightly.

Compound DC Generator



The last type (shown here) is the compound DC generator. Compound generators are the type most often used on cranes. They combine characteristics of both series and shunt generators. The basic output level is set by a regulator in the shunt field circuit that adjusts the current in the shunt field. The regulator may be a rheostat or a voltage regulator. The series field aids the shunt field and provides additional field strength as output current increases and helps to regulate the output voltage. The amount of compounding is determined by the amount of turns in the series field.

Loss of Magnetism

Loss of Magnetism - Causes

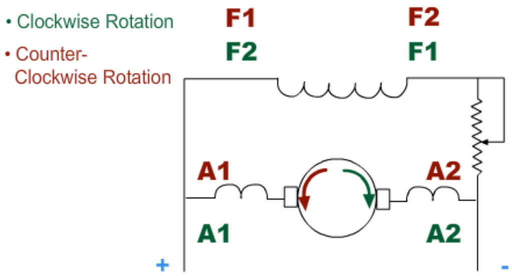
Sometimes DC self-excited generators lose their residual magnetism making it necessary to flash their shunt fields. Reasons a self-excited generator may lose its residual magnetism include: repairs, mechanical stresses, new installation, or simply sitting idle for extended periods of time. Additional evaluation, repair, and field flashing may be needed if a newly installed or repaired self-excited generator produces only a few volts. First, check the shunt field circuit for continuity. Ensure, that the generator is wired per print and that it complies with the appropriate NEMA lead marking convention.

Evaluation

If a self-excited generator produces full voltage or has produced full voltage at one time, it is wired correctly. If that voltage is of the wrong polarity, the generator needs to be flashed for the correct polarity. If the generator was producing full voltage, the connections are unchanged, and the shunt field circuit is functioning, the generator needs to be flashed.

NEMA TERMINAL MARKINGS

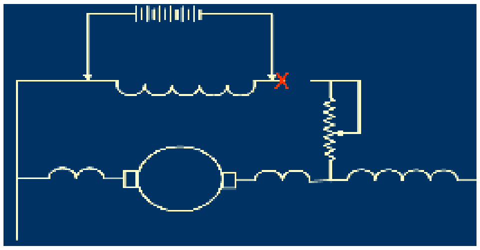
The NEMA MG 1, Section 1, Part 2 terminal marking conventions for DC generators are demonstrated by the animation on this screen.



Clockwise rotation (green) as viewed from the commutator end show the connections made where the shunt winding lead F1; with respect to the F2 lead, is the opposite polarity as the armature lead A1; with respect to the A2 lead.

Counter-clockwise rotation (red) as viewed from the commutator end show the connections made where the shunt winding lead F1; with respect to the F2 lead, is the same polarity as the armature lead A1; with respect to the A2 lead.

FIELD FLASHING



To flash a self-excited generator:

- Disconnect the shunt field from the armature circuit as indicated by the X.
- Determine the correct polarity of the current used for flashing.

The polarity of the flashing voltage should be the same as that desired at the point in the armature circuit where the shunt field was disconnected. If unsure of the polarity, the generator may be temporarily run with the flashing DC source applied to the shunt field. The temporary DC source is correctly polarized when the small generator output voltage is of the correct polarity.

Stop the generator and reverse the shunt field leads, if necessary, so that they agree with the desired polarity of the armature circuit.

- Adjust-out or jump-out any field resistance that remains in the shunt field circuit.
- Apply DC voltage of approximately 10 percent of the generator output for 3 to 5 minutes.

Use a 12-volt battery for a 120-volt DC generator or a 24-volt battery for a 250-volt DC generator.

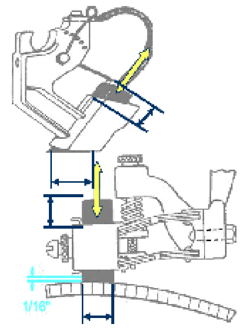
- Remove the temporary DC source and any jumpers.
- Reconnect the shunt field to the armature circuit.
- Test the generator and adjust as needed when the output builds.

This might take 30 seconds or more the first time.

BRUSH CARE

Brush Care

Brushes are the consumable component of generators. Shown here is a diagram of a typical brush assembly. Brushes must be of the proper grade, based on the brush composites or hardness, as recommended by the manufacturer. They must be long enough to provide adequate brush material to accommodate the predicted wear for one maintenance period. Their shunts, the flexible conductor that completes the electrical connection between the brush and the brush holder, must be in good electrical condition. The brush tensioning device must provide the correct pressure for the brush used. The brush holder must be positioned correctly to provide adequate support of the brush which is usually to be about one sixteenth of an inch above the commutator unless otherwise specified by OEM or local engineering instructions. Finally, the brush must be properly seated. The surface of the brush next to the commutator must be smooth, without chipped edges and without imbedded impurities.



Brush Tension

The spring tension on the brush holder establishes, or sets, the brush tension. If adjustable, the spring tension shall be set per generator manufacturer's specifications. In the absence of generator manufacturer's specifications or if the brush composition has been changed per brush manufacturer's recommendations, the spring tension shall be set per brush manufacturer's specifications upon approval of a crane alteration. In the absence of manufacturer's specifications, a suitable brush tension may be specified by the local engineering authority.

For purposes of discussion, let's say that brush tension should be 1.5 – 2.5 pounds per square inch, which is common on many cranes.

The area of the face is calculated by multiplying the brush's width by the brush's thickness.

The calculated area, in square inches, is then multiplied by 1.5 for the minimum tension and 2.5 for the maximum tension.

The actual spring tension is measured using a spring scale or equivalent device attached to the brush shunts and pulled in the direction the brush moves until a freely moving brush is just lifted off the face of the commutator. If the brush tensioning device cannot be adjusted and the brush tension does not meet one of the criteria, the brush tensioning device must be replaced.

COMMUTATOR CARE

Commutator Care

Commutator care is a matter of cleanliness. A clean and properly operating commutator will have a clear, tan shine. To maintain a clean and properly operating commutator follow these steps. Using canvas that has been rolled or wrapped around a stick (or other similar materials and devices as approved), clean the rotating commutator by lightly holding the canvas against its surface. Clean the commutator slots with a soft brush. Clean any carbon dust and dirt from the brushes and brush rigging by vacuuming or blowing with low pressure air. Solvents should only be used as approved and only when absolutely necessary. If solvents are approved and used, be sure any residual solvent has been dried or removed from the generator prior to operation. Check local engineering, management, and safety policies for working on energized, rotating equipment. Always wear proper personal protective equipment for performing required tasks. Obey all approach distances and electrical safety requirements.

"Commutator should have a clear, tan, shine"

Normal Commutator

Shown here are three normal and acceptable conditions that can result from commutator operation. These include: lightly mottled, or spotted, surfaces with random dark patches; slot bar marking, which appears as alternating light and dark films; and a consistent heavy film covering the entire commutator surface. While these conditions pose no immediate concerns, they should be cleaned, as previously discussed, during routine maintenance cycles.

Be lightly mottled with random dark patches

Have slot bar marking with slightly darker film on one bar

Have heavy dark film over entire surface

Commutator Repairs (1)

Shown here are three abnormal and unacceptable conditions that can result from commutator operation. These include: threading - fine lines on the commutator with excessive copper transferred to the brush face; streaking - lines in the film finish on the commutator with some copper transfer to the brushes; and grooving - a loss of commutator material.

Threading is a serious condition involving material loss that can be repaired by stoning, chamfering, and/or by replacing the brushes.

Streaking is slightly different from threading and is considered a moderate concern. It can be repaired by stoning and re-seating the brushes.

Grooving may be caused by improper brush hardness but is often the result of abrasive dust in the environment. Grooving can lead to serious conditions such as overheating and flashover. Machining or replacement of the commutator may be necessary to repair grooving. If abrasive dust in the environment is a problem, air filtering may be required.

These conditions pose immediate concerns and should be corrected or repaired before returning the equipment to operation.

Commutator Repairs (2)

Shown here are three abnormal and unacceptable conditions that can result from commutator operation. These include: heavy slot bar marking - etching of the trailing edge of the commutator due to armature winding imbalance; pitch bar marking - burned spots caused by instantaneous armature over current on a brush; and copper drag - buildup of copper on the trailing edge of the commutator bar due to poor film maintenance.

Heavy slot bar marking is a serious condition that is repaired by rewinding the rotor and machining the commutator.

Pitch bar marking is a minimal concern which can be repaired by cleaning the commutator and inspecting/adjusting the brush rigging.

Copper drag is a moderate concern that can be repaired by slotting, chamfering, stoning and/or replacing the brushes.

These conditions pose immediate concerns and should be corrected or repaired before returning the equipment to operation.

LUBRICATION

Minimal lubrication is usually sufficient. Over lubrication that forces grease into the windings can be more detrimental than under lubrication. Check with your local activity engineering organization for approved and acceptable lubrication procedures. The following is a basic bearing lubrication process.

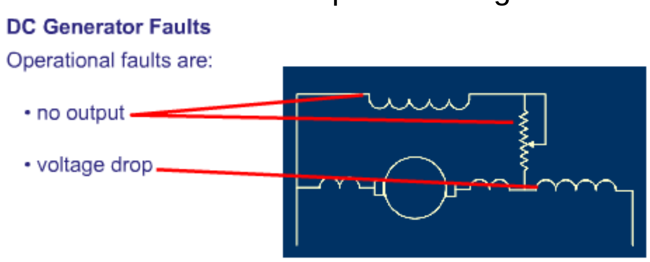
- *stop operation of the equipment ①*
- *perform lockout procedure*
- *wipe all grease fittings clean ②*
- *remove drain plugs ③*
- *free the drain plug of any hardened grease ④*
- *wipe the area around the drain clean*
- *add OEM or engineering specified amount and type of grease ⑤*
- *remove lockout device*
- *restart the equipment*
- *run motor to operating temperature ⑥*
- *stop the motor*
- *wipe the drain plug and filler fitting clean, re-install plugs ⑦*
- *inspect for spilled grease and clean the work site*

Equipment is now ready for service. ⑧

DC Generator Faults

DC Generator Faults (1)

Let's discuss some faults you may encounter when working with DC generators. Two of these faults are "no-output" and "significant-voltage-drop-with-increased-load".



When "no output" occurs, there is a loss of residual magnetism. This requires the field to be flashed. If there is high resistance in the shunt field, check the shunt field circuit and rheostat for open or resistance connections. Make sure the connections are marked correctly and connected properly. Test the armature and field to verify neither are open or shorted.

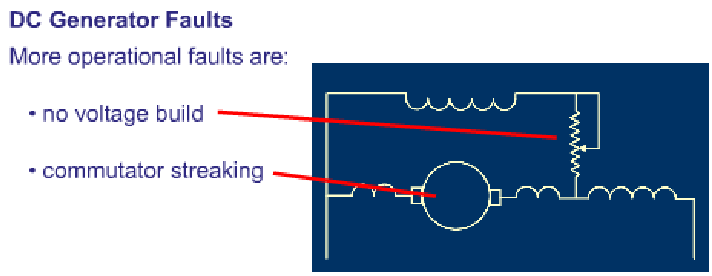
A "significant-voltage-drop-as-load-increases" fault indicates that the series filed may be reversed. Make sure the connections are marked correctly and connected properly. Test the armature for a shorted winding or circuit.

DC Generator Faults (2)

Two more faults you may encounter when working with DC generators are "no-voltage-build-up" and "streaking or threading".

A "no-voltage-build-up" fault indicates the neutral plane is incorrect and needs to be reset. Adjust the position of the brushes, test the armature or field coils for shorts, test the shunt field for high resistance, and check the generator speed level.

Streaking or threading, as discussed earlier, are conditions which required attention. Check the electrical load. If found to be too light, increase the load. Clean the components and the generator. If necessary, install air filters to remove any environmental dust.



SUMMARY AND REVIEW

This module presented basic DC generator theory. You should be able to describe the general construction of a generator including the major parts, components, and assemblies. You should be able to list and discuss the operational differences between series, shunt and compound generators. You were exposed to several types of acceptable and unacceptable conditions often encountered in DC generator maintenance. You should be able to identify these conditions as well as the troubleshooting and repair techniques discussed.

NOTES

DC Generators Knowledge Check

Online questions may appear in a different order that those shown below.

1. True or False

A generator converts electrical energy into mechanical energy.

A: True
B. False

2. Select the best answer.

The armature in a generator is the rotating member that passes through alternating magnetic fields. This creates, or generates _____.

A: electromotive force
B. horsepower
C. alternating current
D. direct current

3. Select the best answer.

What part of the rotor supports the core, coils and commutator?

A: armature
B. winding
C. generator stand
D. shaft

4. Select the best answer.

The ______ of a generator is determined by the amount of voltage generated per armature coil multiplied by the number of coils connected in series.

A. winding wire size
B. neutral plane
C. field strength
D. output voltage

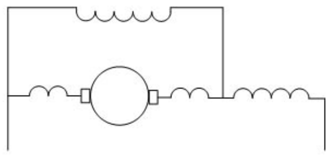
5. Select the best answer.

Interpoles are…

A: small poles placed between the main filed poles
B. wound of a few turns of large wire
C. are connected in series with the armature
D. A and C
E. all listed items are correct

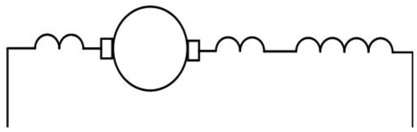
6. Select the best answer.
In a DC generator with a voltage regulator connected in series with the shunt field that controls the voltage and current levels, as the armature current increases, the current and magnetic field in the series field _____ and aids the shunt field.

A. decreases
B. polarizes
C. modulates
D. increases



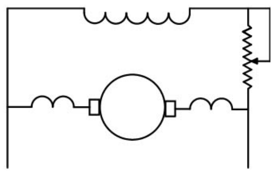
7. Select the best answer.
Select the item that correctly identifies the DC generator represented in the schematic.

A: compound
B. series
C. parallel
D. shunt



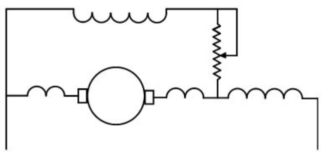
8. Select the best answer.
Select the item that correctly identifies the DC generator represented in the schematic

A. parallel
B. series
C. shunt
D. compound



9. Select the best answer.
Select the item that correctly identifies the DC generator represented in the schematic.

A: parallel
B. compound
C. shunt
D. series



10. Select all that apply.
Select the items that may cause a self-excited generator to lose its residual magnetism.

A: sitting idle for extended periods of time
B. high stranding
C. new installation
D. repairs
E. mechanical stress

11. True or False
To flash a self-excited generator, apply a DC voltage of approximately 10% of the generator output for 3-5 minutes.

A: True
B. False

12. Select the best answer.
The surface of the ______ next to the commutator must be smooth, without chipped edges and without imbedded impurities.

A. generator
B. rotor
C. brush
D. armature

13. Select the best answer.
The spring tension on the brush holder shall be set per the ______ manufacturer's specifications.

A: spring
B. armature
C. commutator
D. generator

14. Select the best answer.
Select the condition from the list that can be described as lines in the film finish starting with copper transferred to the brush face.

A. streaking
B. threading
C. normal
D. slot bar marking

15. Select the best answer.
Select the condition from the list that can be described as a commutator with a lightly mottled or spotted surface and random dark patches.

A: threading
B. slot bar marking
C. normal
D. streaking

16. Select the best answer.
Over lubrication that forces grease into the windings can be more detrimental than under lubrication.

A: True
B. False

17. Select all that apply.
You are troubleshooting a DC generator and receive a “no voltage build-up” fault which indicates the neutral plane is incorrect and needs to be reset. Select the item(s) from the following list that best describe your follow-up actions.

A. test the shunt field for high resistance
B. flash the field coils
C. test the armature for field coils for shorts
D. adjust the position of the brushes
E. check the generator speed level

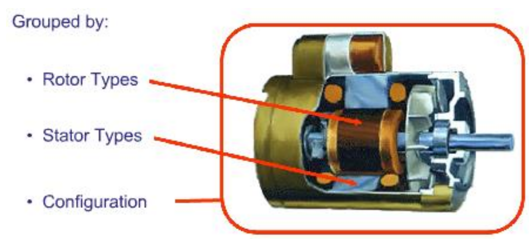
AC MOTORS

LEARNING OBJECTIVES

Upon successful completion of this module, you will be able to

- Identify the types of AC motors
- Describe operating characteristics of each type
- Describe basic AC motor maintenance

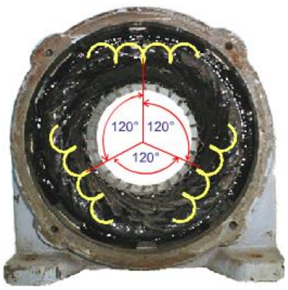
TYPES OF AC MOTORS



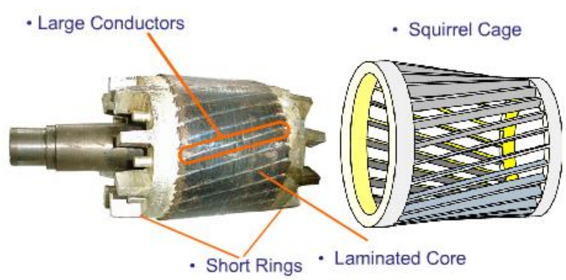
AC motors can be grouped by rotor types, stator types and configuration. Universal motors are identical to DC series motors. Such motors are not suitable for crane function use. Repulsion motors are similar to induction motors with windings, commutators, and brushes added to provide excellent starting torque. The additional circuitry makes them a poor choice for use as a crane function motor.

THREE PHASE STATORS

Three phase stators provide the most efficient and reliable rotating fields. They have three sets of windings laid into the slots of a laminated core. Also, each set is offset by 120 degrees such as to provide an effective field that rotates through the complete line cycle. Finally, this stator provides superior starting and running torque and is the most common type of AC motor stator used for crane functions.



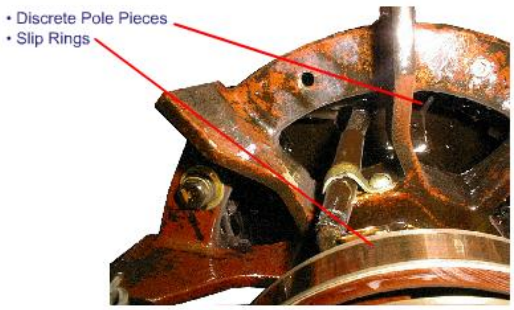
ROTOR TYPES: INDUCTION ROTOR



The next way to group AC motors is by the type of rotor. Induction rotors have large conductors laid into the slots of a laminated core and connected at each end by shorting rings. The conductors and shorting rings form an electrical circuit resembling a squirrel cage, which is so named for this resemblance.

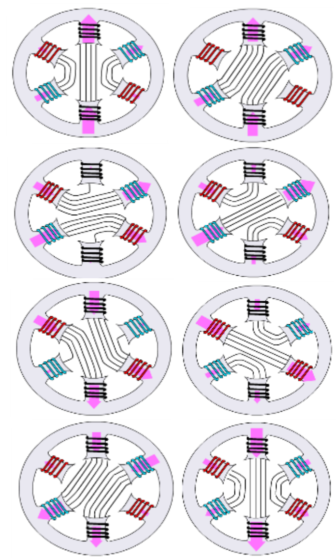
Rotor Types: Wound Rotors

Wound rotors have discrete pole pieces wound with small wire and have slip rings as means of connecting those windings to external circuitry. A single phase rotor with external excitation applied forms a synchronous motor. These motors have poor starting torque and are inappropriate for use as crane function motors. A three phase rotor, connected to a resistor bank, forms a variable torque AC motor.



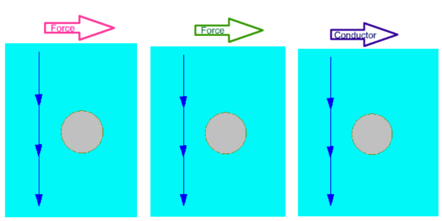
Theory of Operation

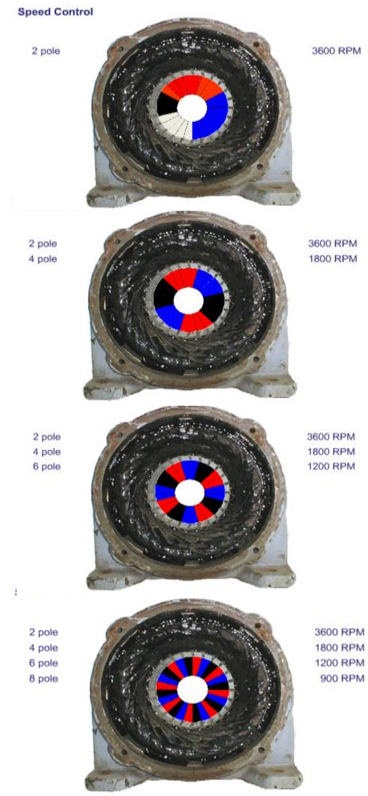
The stator sets up a rotating field as described earlier. The type of stator dictates just how the field will rotate through the rotor. For the purpose of this explanation, we will use a three phase stator. As three phase power is applied to the three groups of windings, (A, B, and C), alternating magnetic fields are produced in each group in turn. The flux from these poles combines in the center to produce a rotating field. A conductor placed in that field will be swept by the rotating magnetic field.



Inducing Rotor Current

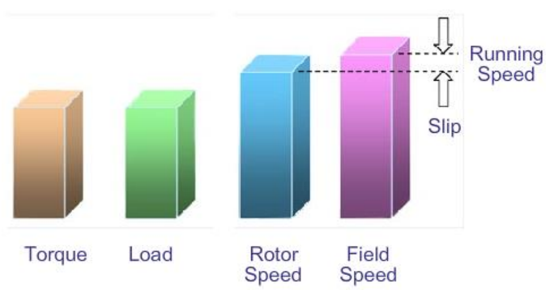
When the moving field acts upon the electrons in that conductor, current is induced. The magnetic field, represented by the blue arrows, is in motion from left to right. Using the convention that those arrows flow from north to south, this interaction will cause the electrons in the conductor to flow away from you. As those electrons move away from you, they produce a magnetic field that encircles themselves and the conductor in a counter-clockwise direction. These rotor fields interact with the stator's fields. Using the magnetic axiom that like poles repel and unlike poles attract, you can see that a force is acting on the electrons that would tend to make them move to the right. Since the electrons cannot leave the conductor, the force acting on them is transferred to the conductor. If the conductor is free to move, it will tend to follow the magnetic field.





SPEED CONTROL

Considering those same axioms, the two ways to control the speed of an AC motor are to control the speed of the rotating field or control the torque. The speed of the rotating field can be controlled in two ways. First, the stator can be wound to allow multi pole configuration. A stator can have a high speed 2-pole connection that provides a field that rotates at 3600 RPM and a low speed 4-pole connection that provides a field that rotates at 1800 RPM. It can also have a low speed 6-pole connection that provides a field that rotates at 1200 RPM or a low speed 8-pole connection that provides a field that rotates at 900 RPM. Although more than two sets of windings are possible, they tend to be impractical. Two speed motors, however, are very common and are found on many category 3 and pendant operated cranes. Another way to control the speed of an AC motor is by supplying the motor from a variable frequency controller. This method of control is covered in the controller module.

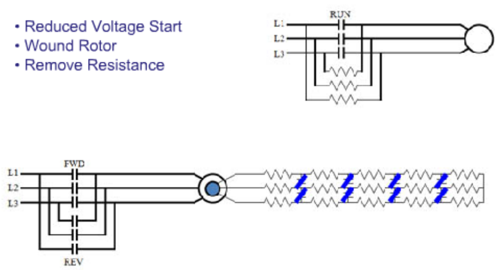


STARTING INDUCTION MOTORS

This reduction can then be applied to starting the motor. The field is rotating at synchronous speed. Synchronous speed, in revolutions per minute (rpm), is equal to the line frequency, in cycles per second (Hertz or Hz), times 120 (to convert seconds to minutes for two poles), divided by the number of poles. With the rotor speed at zero, the armature resistance is low, the relative speed is high, and maximum torque is produced. Assuming that the load is constant, if the motor torque is greater than the load, the motor will speed up. The faster the motor runs, the less the relative speed, the less current is induced in the rotor, and the less torque is produced. When the torque is reduced to point equal to the load, then running speed for that load has been reached. The difference between the running speed and synchronous speed is called “slip”. It can then be said that motor torque is proportional to slip. An induction motor will slip the amount needed to produce the load torque.

VARIABLE TORQUE

At present, the most common method of controlling the speed of an AC motor is to control its torque. In that the torque of the motor is proportional to the field strength, varying the stator voltage can control the motor's speed. This, until recent innovations in electronic controllers, was impractical for hoist functions. However, reduced voltage is a common method of starting large induction and synchronous motors. The torque of the motor is also proportional to the armature current. The transition from DC to AC, both in industrial use and on cranes, was made possible by installing wound rotors in their motors and connecting those rotors to an external resistor bank. A drum controller is a multi-position, multi-connection switch and is used to reduce the amount of rotor circuit resistance, increasing rotor current, and increasing the motor speed.



Magnetic controls, using relays and contactors to connect the different resistances, are the most common type of controller used for crane functions. This type of control has limitations and the use of secondary brakes, mechanical and electric load brakes are needed to improve the operating characteristics on cranes. This type of control is addressed in the controller module.

MOTOR LIFE

The key to long trouble-free motor life is proper maintenance. Maintaining a motor in good operating condition requires *periodic inspection* to determine faults and *deficient conditions*. The frequency and thoroughness of inspections depend on several factors. First, the *number of hours* the motor operates. Periodic checks will reveal if motors are exposed to detriments such as water, acid, alcohol, fumes, excessive dust, chips, or lint and whether or not further investigation or corrective action is required. Another factor is the *nature of service*. Motors that are subject to heavy loads require more frequent inspection than light duty motors. Finally, *environmental conditions* may be a factor in establishing the frequency and thoroughness of inspections. Make certain that objects that will cause problems with the motor's ventilation system are not placed too near the motor and do not contact the motor's moving parts.

FIRST SIGN OF TROUBLE

Learn to detect the first signs of problems by knowing what each properly running motor *sounds like, feels like and smells like*. Be alert to any unusual condition. Learn to recognize the noise caused by metal-to-metal contact which may indicate bad bearings, etc. Learn to detect abnormal odor, which can indicate scorching insulation varnish. Feel the bearing housing for evidence of vibration and unusual noises and excessive heat. A standard screwdriver with the blade on the bearing housing and the handle clasped with the hand while the ear is positioned so as to rest on the cupped hand will magnify the noise. Also, inspect the bearing housings for the possibility of creeping grease on the inside of the motor, which might harm the insulation.

AC MOTOR MAINTENANCE (1)

AC Motor Maintenance

Components begin to deteriorate as soon as they are installed and failure of some components in the system will ultimately require some basic maintenance. The five main areas of AC motor maintenance are windings, bearings, cleanliness, brushes and slip rings.

Winding Maintenance

The maintenance concerns for the windings deals mostly with evaluation. Meggering is a resistive check made on all windings. A megger check consists of isolating the

windings by disconnecting as needed, connecting a megger to the winding and to ground, and taking the reading. In general, acceptable megger readings of 20 mega-ohms for new or rewound windings, 10 mega-ohms for repaired windings, or 2 mega-ohms for working motors are no cause for concern. Your local engineering authority may choose to set other criteria. Low megger reading of less than 2 mega-ohms should be monitored. Readings that rise and fall with temperature and humidity indicate the insulation is not breaking down and are not of concern. Readings that continue to drop over time indicate the insulation is breaking down. Your local engineering authority shall evaluate the megger readings for trends to determine when the winding shall be removed, rewound, reinsulated, or replaced. Cleaning involves wiping down the exposed areas. The use of compressed air or solvents is more likely to worsen the condition than improve it.

Bearing Maintenance

Minimal lubrication is usually sufficient. Over lubrication, that forces grease into the windings, can be more detrimental than under lubrication. Check with your local activity engineering organization for approved and acceptable lubrication procedures. The following is a basic bearing lubrication process.

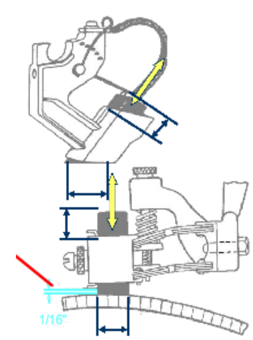
stop operation of the equipment ①
- *perform lockout procedure*
- *wipe all grease fittings clean* ②
- *remove drain plugs* ③
- *free the drain plug of any hardened grease* ④
- *wipe the area around the drain clean*
- *add OEM or engineering specified amount and type of grease* ⑤
- *remove lockout device*
- *restart the equipment*
- *run motor to operating temperature* ⑥
- *stop the motor*
- *wipe the drain plug and filler fitting clean, re-install plugs* ⑦
- *inspect for spilled grease and clean the work site*

Motor is ready for service. ⑧

Cleanliness

An important step in the maintenance of AC motors is cleanliness. The frequency of cleaning motors will depend on the type of *environment* in which it is used. Keep both the interior and exterior of the motor free from dirt, water, oil, and grease. Motors operating in dirty areas should be periodically disassembled and thoroughly cleaned. If the motor is totally enclosed, fan-cooled or non-ventilated, and is equipped with automatic drain plugs, they should be free of oil, grease, paint, grit and dirt so they don't clog up.

AC Motor Maintenance (2)

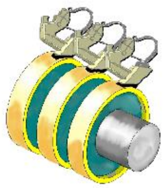


Brush Maintenance

Brushes are the consumable component of AC motors. Shown here is a diagram of a typical brush assembly. Brushes must be of the proper grade, based on the brush composites or hardness, as recommended by the manufacturer. They must be long enough to provide adequate brush material to accommodate the predicted wear for one maintenance period. Their shunts, the flexible conductor that completes the electrical connection between the brush and the brush holder, must be in good electrical condition. The brush tensioning device must provide the correct pressure for the brush used. The brush holder must be positioned correctly to provide adequate support of the brush, which is usually to be about one sixteenth of an inch above the commutator unless otherwise specified, by OEM or local engineering instructions. Finally, the brush must be properly seated. The surface of the brush next to the commutator must be smooth, without chipped edges and without imbedded impurities.

Slip Ring Maintenance

The slip rings are the collectors that conduct the wound rotor to the external circuitry. To insure good electrical conduction, a proper film must be maintained to the face of the slip rings. The face of the slip rings must be round and true to the axis of rotation. If the rings are more than a few thousandths out of round, brush wear will be greatly increased. In such cases, the ring may need to be removed and machined. The



condition of the face must be free of grooves, pits, and gouges. If such conditions exist, the slip rings can be stoned-in-place. Coarse, medium, fine, and finish stones are used, as needed, to remove surface blemishes. With the slip rings free of blemishes and true to the axis of rotation, the film condition should be clear and varnish-like. A chalky or dirty looking film requires attention and maintenance. If the surface is grooved, brush tension may be too high, the brush may be too hard, the brush face may be contaminated, or it may be a combination of all three conditions. If the surface appears to be chalky, brush tension may be too light; there may be detrimental contaminants in the atmosphere, or both.

Lubrication

Most motors are properly lubricated by the manufacturer and it is not necessary to lubricate them at the time of installation. However, if a motor has been in storage for a period of 6 months or longer, it should be lubricated again before starting. The quantity of grease is important. Remember, too much grease is as detrimental as insufficient grease. The type of grease is important. Unless specified otherwise by the motor’s manufacturer or your local engineering group, Mobil product 28 or equivalent shall be used on all motors.

SUMMARY AND REVIEW

In this module, you learned how to

- identify the types of AC motors
- describe operating characteristics of each type of motor, and
- describe basic AC motor maintenance

NOTES

AC Motors Knowledge Check

Online questions may appear in a different order that those shown below.

1. True or False

A single phase rotor with external excitation applied, forms a synchronous motor. These motors have good starting torque and are excellent for use as a crane function motor.

A. True
B. False

2. Select the best answer.

Three phase stators provide the most _____ and _____ rotating fields.

A. reliable and efficient
B. stable and maintainable
C. torque and resistive
D. horsepower and advanced

3. Select all that apply.

AC motors can be grouped by:

A. bearing types
B. stator types
C. all listed items are correct
D. rotor types
E. configuration

4. Select the best answer.

You have a three phase stator. As power is applied to the three groups of windings…

A. alternating magnetic poles are produced
B. a rotating field is produced
C. conductor requirements are reduced
D. A and B
E. all items are correct

5. True of False

Induction motor synchronous speed can be determined by the following formula:

$$\text{Synchronous Speed (rpm's)} = \frac{\text{line frequency (cycles/sec)} \times (60 \text{ sec/min} \times \text{\# of poles})}{(\text{\# of poles})}$$

A. True
B. False

6. Select the best answer.
How can the speed of the rotating field be controlled?

A. by inverting line frequency
B. using a variable frequency controller
C. the stator can be wound to allow multi-pole configuration
D. B and C
E. All listed items are correct

7. Select all that apply.
What factors impact the frequency and thoroughness of motor inspections?

A. type of crane h
B. environmental concerns
C. ours of operation
D. nature of service (light/heavy duty)

8. Select all that apply.
Areas of AC motor maintenance include:

A. windings
B. bearings
C. cleanliness
D. slip rings
E. bushes

9. Select the best answer.
What item in the list below can be described as a resistive check on windings?

A. shunting
B. meggering
C. tamping
D. analyzing

10. True or False
The brush holder must be positioned correctly to provide adequate support of the brush which is usually about one sixteenth of an inch above the commutator unless otherwise specified by OEM or local engineering instructions.

A. True
B. False

11. True or False
If the slip ring is more than a few thousandths of an inch out of round, brush wear will be greatly increased.

A. True
B. False

12. Select the best answer.
The frequency of cleaning motors will depend on the type of ________ in which it is used.

A. all listed items are correct
B. system
C. void
D. environment

ALTERNATORS

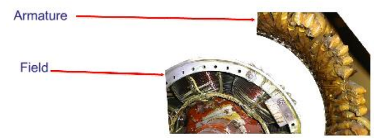
Learning Objectives

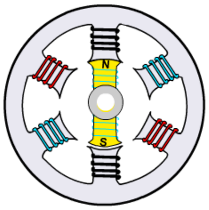
Upon successful completion of this module and to ensure the reliability of alternators, you will be able to

- Describe basic alternator maintenance
- Describe basic repair and troubleshooting techniques

Alternator

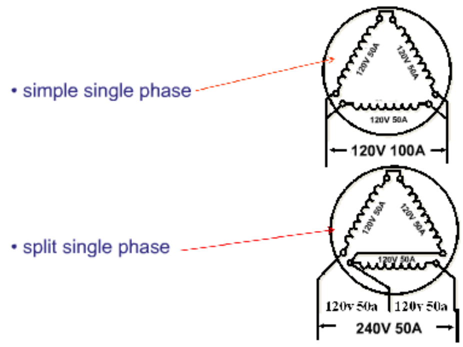
Alternators convert mechanical energy to AC voltage using the principles of magnetic induction. The armature is normally the stationary component or stator. It is connected directly to the output therefore the voltage and current is not limited by slip-rings and brushes. The field windings are normally wound on the rotating component or rotor. By injecting DC voltage in the rotor windings, a rotating field is created which induces voltage in the stator.





Alternator Output

The output frequency is dependent on the speed of the rotor and the number of field poles, therefore the prime mover must be regulated to maintain a constant speed and a stable alternator frequency. The output voltage is dependent on the excitation, which is the current input to the rotor and creates the rotating magnetic field.



Single Phase Alternator

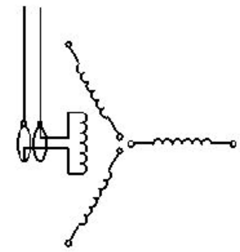
Most single phase alternators are actually multiple phase alternators in which the output windings are re-connected for single phase. Three sets of windings are the most common winding multiple.

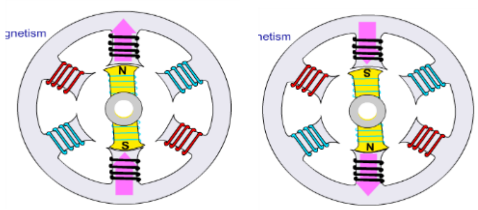
A three-phase alternator, connected as shown in the upper diagram, produces simple-single-phase output at the rated voltage - and two times the rated current. The same alternator can be connected, as shown in the lower diagram, to produce a split-single-phase output at the rated voltage on each half - and two times the rated voltage end-to-end. If the center leg is grounded, the alternator's output will be two one-hundred-twenty-volt AC circuits to ground - and one two-hundred-forty-volt circuit with a neutral.

This is compatible with standard lighting circuits and common equipment and is suitable for use as lighting or accessory power on cranes.

Three-Phase Alternator

The next type of alternator is the three-phase alternator. All large alternators used for main power on cranes will have rotating fields and a three-phase armature stator. Older alternators supply the DC for the rotating field through slip-rings. The alternator is self-excited if the current to the rotor is rectified from the alternator's output. The alternator is externally excited if the current to the rotor is from any other source than the alternator's output. The output voltage is proportional to the field current.



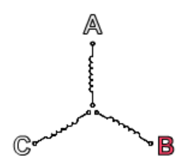


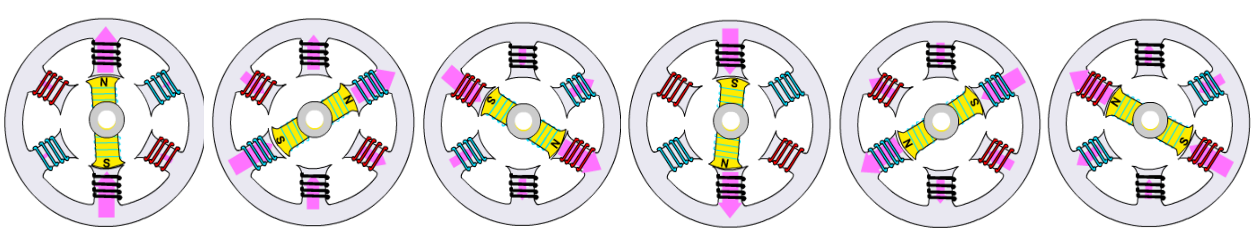
Alternator Operation

When the alternator is operating, the rotating field induces magnetism in the stator, first in one direction, and then the other. This alternating magnetism produces an alternating current in the stator windings.

Phase Rotation

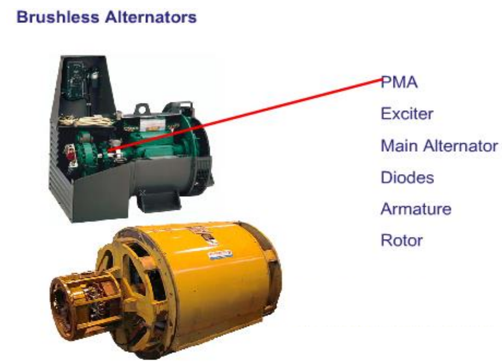
In a three-phase alternator, the same rotating field produces an alternating current in each of the other phase windings, with B phase following A phase by one-hundred-twenty degrees and C phase following B phase by one-hundred-twenty degrees.





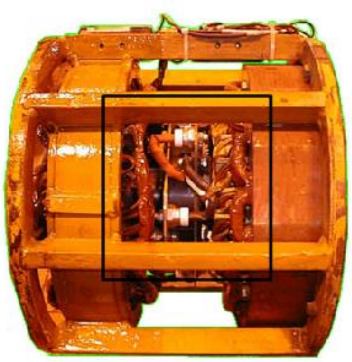
Brushless Alternators

Through the years, industry has demanded more reliable alternators. To meet that demand, the brushless alternator was developed, which eliminated the need for slip rings. An exciter is mounted on the main alternator and its armature is mounted on the main shaft. A bank of diodes is mounted on the main shaft and connected to the main alternator's rotation field. Other parts include the permanent magnet alternator, or PMA, the armature, and the rotor.



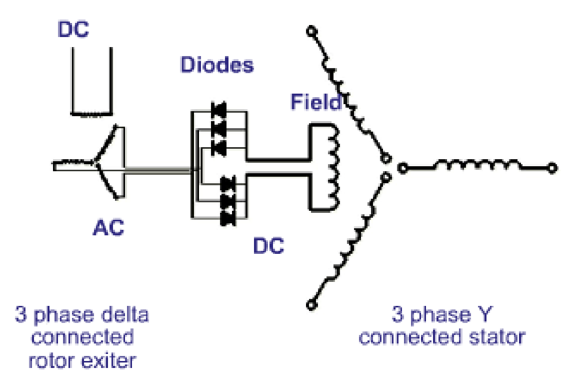
Flying Diodes

The diodes are installed directly on the exciter rotor and are connected directly to the rotating fields. These are called "flying diodes". There are two plates mounted on an insulator, which, in turn, is bolted to the main shaft. Three negative stud diodes are mounted on the right plate, and three positive stud diodes are mounted on the left plate. The leads of one positive stud diode and one negative stud diode are connected to an insulated stud, as is one phase of the exciter rotor. The other two phases are connected in the same manner. The two plates are connected to the main rotating field using insulated leads, pulled into channels in the shaft.



Operation

A brushless alternator operates as follows. A DC control current is applied to the stator field of the exciter. The exciter generates three-phase AC proportional to the amount of control current. The diodes rectify the AC into DC, which supplies current directly to the main alternator's rotating field.



External Excitation

One method of ensuring a reliable source for external excitation is to mount a PMA on the same shaft as the exciter, diodes and main field. This alternator consists of an armature stator and permanent magnets mounted on the shaft. As the magnets rotate, they induce alternating magnetic fields in the stator's windings inducing alternating voltage in each. Now that we have addressed how alternators work, we can cover some of the basic actions that keep them working.

Alternator Maintenance

Alternator maintenance can be divided into three groups. First is preventive maintenance, which is the scheduled maintenance necessary to keep the alternator in good running condition. Second is troubleshooting and repair, which includes the evaluation and correction of deficient conditions with the alternator in installed location. Third is overhaul, which involves repairs that require the alternator to be removed from the crane.

Preventive Maintenance

The preventative maintenance actions needed to keep an alternator properly running are bearing maintenance, winding maintenance and cleanliness. First, we will discuss bearing maintenance.

Lubrication

Minimal lubrication is usually sufficient. Over lubrication, that forces grease into the windings, can be more detrimental than under lubrication. Check with your local activity engineering organization for approved and acceptable lubrication procedures. The following is a basic bearing lubrication process.

- *stop operation of the equipment ①*
- *perform lockout procedure*
- *wipe all grease fittings clean ②*
- *remove drain plugs ③*
- *free the drain plug of any hardened grease ④*
- *wipe the area around the drain clean*
- *add OEM or engineering specified amount and type of grease ⑤*
- *remove lockout device*
- *restart the equipment*
- *run motor to operating temperature ⑥*
- *stop the motor*
- *wipe the drain plug and filler fitting clean, re-install plugs ⑦*
- *inspect for spilled grease and clean the work site*

Equipment is now ready for service. ⑧

SPECIAL CONSIDERATION

Special consideration must be made where the bearing being lubricated is not readily accessible. The bearing housing shown is equipped with a remote fill hose and no drain. This housing is completely inaccessible when the alternator is bolted to the diesel. Precautions are needed to prevent over pressurization and over lubrication of such bearings.

OEM recommendations should always be followed with regard to the type, amount, and frequency of lubrication. If OEM specifications are not available, two strokes from a low pressure hand operated grease gun using Mobil Product 28 (or equivalent) every four months while operating, will provide adequate lubrication for large alternator bearings.

WINDING MAINTENANCE

The maintenance concerns for the windings deals mostly with evaluation. Meggering is a resistive check made on all windings. A megger check consists of isolating the windings by disconnecting as needed, connecting a megger to the winding and to ground, and taking the reading. In general, acceptable megger readings of 20 mega-ohms for new or rewound windings, 10 mega-ohms for repaired windings, or 2 mega-ohms for working motors are no cause for concern. Your local engineering authority may choose to set other criteria. Low megger reading of less than 2 mega-ohms should be monitored. Readings that rise and fall with temperature and humidity indicate the insulation is not breaking down and are not of concern. Readings that continue to drop over time indicate the insulation is breaking down. Your local engineering authority shall evaluate the megger readings for trends to determine when the winding will be removed, rewound, reinsulated, or replaced. Cleaning involves wiping down the exposed areas. The use of compressed air or solvents is more likely to worsen the condition than improve it.

CLEANLINESS

Alternator cleanliness has three areas of concern.

The removal of foreign material from its interior is beneficial in ensuring reliable alternator operation. Common dust does not pose a hazard to the alternators insulation. However, a buildup of dust on the windings reduces the air flow and concerns for overheating require the interior of the alternator be kept as clean as possible.

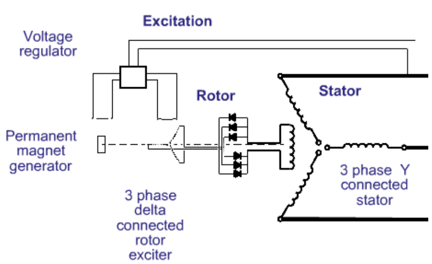
Moisture poses no hazard for alternator windings. However, in combination with conductive contaminants, moisture can cause problems. Oil and solvents tend to break down the insulation in the windings and should be removed from the interior of the alternator.

Compressed air is sometimes used to blow away any dust. However, compressed air contains moisture, which may cause other problems. The exterior of the alternator should be kept clean and wiped down.

The area around the alternator must be kept clean and free of debris. A lot of air is drawn through the alternator to cool its windings. That air comes from the general area around the unit and must be kept free of contaminants.

TROUBLESHOOTING AND REPAIR

In addition to scheduled maintenance, alternators need to be repaired when they fail or when an unreliable or unsafe condition is detected. Determination of the problem and involved components or "troubleshooting", dictate whether the corrective actions lend themselves to repairs in place, removal and overhaul or replacement of the entire unit.

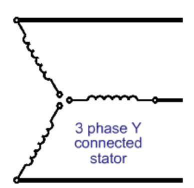


DIVIDE THE SYSTEM

When troubleshooting an alternator, it is often helpful to divide the system into *stator circuits*, *rotor circuits* and *excitation circuits*. First, we will look at problems in the stator circuits.

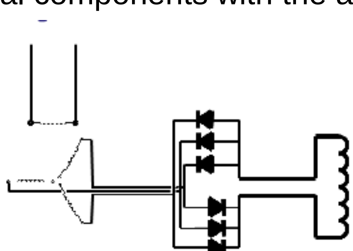
TROUBLESHOOTING THE STATOR

The stator is the most reliable part of the alternator. Typically, problems with the stator are the grounded phase and the unbalanced phase. In the grounded phase, you should lift all leads and verify the ground. Then, remove the alternator to be rewound or repaired. In the unbalanced phase, you verify improper resistance in one phase and remove the alternator to be rewound, reinsulated, or repaired. Should there be no output at all - the problem is not likely to be in the stator.



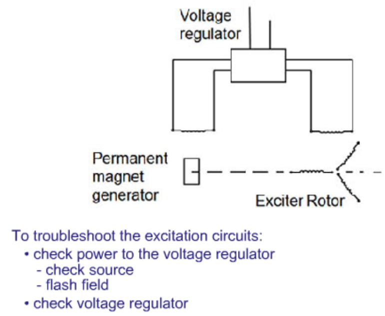
TROUBLESHOOTING THE ROTOR

The rotor, being in motion when the alternator is running, is best checked by testing the individual components with the alternator secured. If there is no output with continuity on the exciter field and voltage applied, then troubleshoot the rotor. First, megger and continuity-check the rotating field. Next, lift the leads and megger and continuity-check the exciter armature. Finally, lift the leads and check the diodes per the procedure shown in the Instruments Module.



To troubleshoot the rotor:
1. Megger and continuity check main field
2. Megger and continuity check exciter armature
3. check diodes

Troubleshooting Excitation



If the alternator is running with continuity on the exciter field and no voltage present, then troubleshoot the excitation circuits. Check power to the voltage regulator. If the regulator's source is a generator or alternator and there is no voltage present, then repair the source. If the regulator's source is the alternator's output, the alternator is self-excited. The main field should be flashed per the detailed description in the generator module. Flashing re-establishes residual magnetism by passing rated direct current through the isolated main field for at least 5 minutes in same direction as supplied by the diodes. If proper voltage per nameplate data is being applied to the voltage regulator and there is no output to the exciter field, then repair or replace the voltage regulator.

Overhaul

If the alternator needs to be rewound or reinsulated, the repair is best done at an appropriate facility. However, you should take care to adequately mark and record the alternator leads for transport. Also, mark, record, and protect the leads on the crane. Next, verify that the bearings are properly lubricated prior to reinstallation. Once in place, verify the correct hookup of the alternator leads. Finally, torque all electrical connections per manufacturer's data.

Summary and Review

In this module, you learned the basic maintenance, repair and troubleshooting techniques necessary to assure the reliability of alternators.

NOTES

Alternators Knowledge Check

Online questions may appear in a different order that those shown below.

1. True or False

The output frequency of an AC alternator is dependent on the percentage of brush to commutator contact and brush rigging spring tension, therefore the prime mover must be regulated to maintain a constant speed and a stable alternator frequency.

A. True
B. False

2. Select the best answer.

Alternators convert ________ to ________ using the principle of magnetic induction.

A. electrical energy - rotating mechanical force
B. electrically induced torque - horsepower
C. mechanical energy - AC voltage
D. mechanical energy - DC voltage

3. Select the best answer.

What must be done with the current supplied to the rotor from the alternator's output to allow the alternator to be self-excited?

A. phased
B. rectified
C. reduced
D. inverted

4. Select the best answer.

How is alternating current produced in the AC alternator?

A. three phase alternator produces simple single phase output at the rated voltage and at 2 times the rated current
B. the filed pole solenoids alternate input-output frequencies
C. the rotating field induces magnetism in the stator, first in one direction, and then the other
D. the stator repeats diametrically opposite phases within in the windings thereby producing magnetically alternate frequency outputs

5. Select the best answer.

Select the term from the list below that best identifies the following description: a DC control current is applied to the stator field of the exciter. The exciter generates three phase AC proportional to the amount of control current. The diodes rectify the AC into DC which supplies current directly to the main alternator's rotating field.

A. flying diode
B. permanent magnet alternator
C. armature stator
D. brushless alternator

6. Select the best answer.
At what point do you replace brushes in a flying diode, self-excited, AC alternator?

A. never
B. when brush length is insufficient to last until the next maintenance period
C. 50% brush wear
D. none of the items listed
E. when the alternator no longer self-excites

7. Select the best answer.
What would most likely cause the alternator frequency to be too high or too low?

A. malfunctioning diodes
B. prime mover operating at the wrong RPM
C. high resistance in the stator
D. A and C

8. Select all that apply.
Alternator maintenance can be divided into groups that include…

A. none of the items listed
B. overhaul
C. troubleshooting
D. preventive maintenance

9. Select all that apply.
Alternator maintenance concerns include:

A. bearing maintenance
B. winding maintenance
C. cleanliness
D. none of the items listed

10. True or False
Minimal lubrication is usually sufficient. Over lubrication can be more detrimental than under lubrication.

A. True
B. False

11. Select the best answer.
When lubricating inaccessible internal bearings, you should follow…

A. OEM specifications
B. Larry's Lube Log
C. local engineering specifications
D. in the absence of A, follow C

12. Select the best answer.
Moisture and dust can harm an alternator in the following ways:

A. builds up and reduces air flow
B. inverts continuity
C. damages the interior of sealed bearings
D. erodes wire insulation

13. Select the best answer.
What process helps determine the problem(s), the component(s) involved, and how corrective actions should be implemented?

A. overhaul
B. troubleshooting
C. meggering
D. excitation

14. Select the best answer.
Typical problems with the stator include:

A. unwound field
B. unbalanced phase
C. grounded phase
D. B and C
E. All listed items are correct

15. Select the best answer.
Flashing re-establishes residual continuity by passing the rated alternating current through the isolated main field for at least 5 minutes in the opposite direction than that supplied by the diodes.

A. True
B. False

CONTROLLERS

Learning Objectives

Upon successful completion of this module you will be able to describe basic maintenance, repair and troubleshooting of controllers.

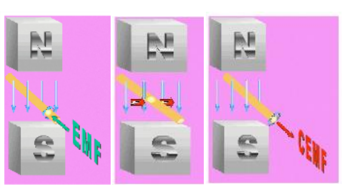
Types of Controllers

A controller is a device that connects or regulates the electrical power supplied to a motor.

- A *manual controller* is a device that uses switches or contacts, to connect or regulate the power to a motor.

- A *magnetic controller* is a device that uses relays or contact to connect or regulate the power to a motor. This type of controller uses moving parts to activate switches, relays and contacts. These switches, relays and contacts may be activated by an input device called a master switch. Master switches can also be activated by the use of sensitive switches (sometimes called micro-switches), limit switches, interlock switches, sensors.

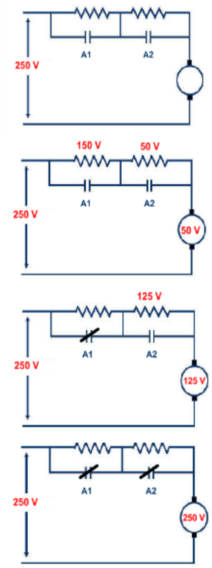
- A *solid state controller*, also known as a “static” or “electronic” controller, has no moving parts. This increases reliability and decreases potential for failure. Solid state technology uses semiconductors to regulate the impulse signal and allows the signal to pass through to the appropriate device. These types of controllers use no moving parts and when solid state technology is used on a pendant controller, it sends an electronic signal to the processor. The processor then sends and electronic signal to the appropriate function.



Counter Electromotive Force

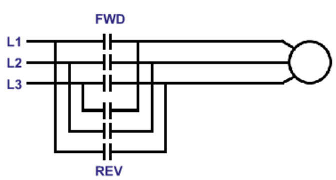
Let’s review counter electromotive force (CEMF) so we can see how it affects control. Because there is no CEMF when the armature is stationary, the value of the current is determined by the resistance alone. Therefore, the need to limit the starting current of a DC motor requires a device that will reduce armature voltage to restrict armature current to a safe value.

RESISTIVE START



One method to reduce armature voltage to restrict armature current is to add resistance to the armature to lower the voltage applied to the armature winding during the starting period. When line voltage is applied, the motor starts with only a fraction of the voltage developed across the armature. Resistance is removed as speed increases, which allows more voltage to be applied across the armature. Full voltage is applied across the armature to allow the motor to reach its rated speed. The method used depends upon the type of motor, the type of load, and the type of voltage (AC or DC) available from the source. Other factors such as space, cost of installation and maintenance, and efficiency of operation must also be considered. Fractional horsepower motors can frequently be started without the use of current-limiting equipment. For motors rated at 1 horsepower and higher, some type of reduced voltage is used.

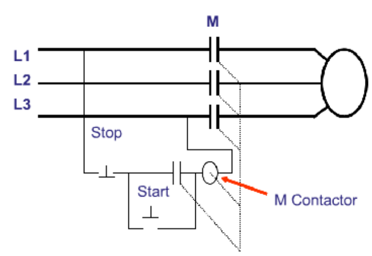
AC CONTROLLER CHARACTERISTICS



Let's discuss some basic AC motor controller characteristics. In an induction motor, connections are made directly across the line because it will develop a higher starting torque than if it is started with a reduced voltage. This provides rapid acceleration to rated speed and permits starting under load. The starting current, however, will range from 4 times to 6 times the full-load current. Because of their rugged construction and method of operation, squirrel-cage induction motors will not be damaged by high starting currents. With very large motors, however, the high starting current may cause too much voltage fluctuation in the power lines or may impose too great a stress on the driven machinery. Under these conditions, the voltage must be reduced during the starting period. Many factors must be considered when selecting starting equipment. These factors include starting current, voltage (line) drop, type of load, motor protection, and operator safety.

ACROSS-THE-LINE CONTROL

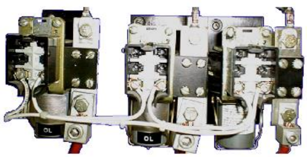
Motors that are to be started under full voltage generally use a control called across-the-line. This mechanism usually consists of a magnetic relay, an overload protective device, and an arrangement that can provide low-voltage protection. A momentary push-button station is often used in conjunction with the across-the-line starter. This type of installation consists of two circuits; the main circuit and the control circuit. The main circuit contains the conductors and devices from the supply to the motor. The control circuit contains the magnetic coil, overload contacts, auxiliary contacts, push buttons, and the conductors that connect them together. For many installations, control transformers are used to provide a lower voltage for the control circuits. If a control transformer is used, it may be contained within the same enclosure as the across-the-line starter, or it may be located elsewhere, supplying the power for the control circuit of more than one starter.



OVERCURRENT DEVICES

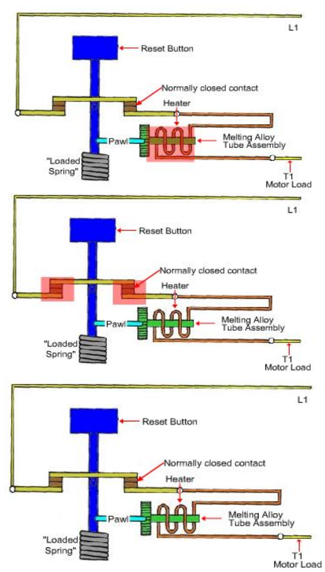
There are two categories of over current protection: ‘short-circuit and/or ground fault protection’ and ‘overload protection’.

Short-circuit and/or ground fault protection is provided by devices capable of instantaneously interrupting the large currents encountered when conductors short together or to ground. These devices may be fuses, breakers, or line contactors equipped with instantaneous trips. The device opens the branch circuit to the function controller.

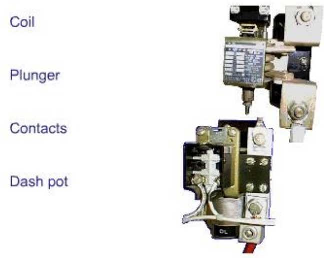


Overload protection is provided by devices capable of protecting motors from overheating by evaluating motor overloads as an inverse time function of the motor current. These devices may be fuses, breakers, motor contactors equipped with inverse time trips, or thermal devices implanted in the motor that interrupt loaded motion. Usually, installed in the motor circuit, both protections may be provided by a single unit if properly rated and equipped. Some fuses, breakers, and electronic over current devices are so rated.

OVERLOAD PROTECTION



One of the most common types of inverse-time overload devices is the thermal overload. The motor current flows through a resistive shunt (heater) that has a thermal device. When the motor current exceeds a value that causes overheating in the motor, the current through the heaters generates enough heat to activate the thermal device, which opens the normally closed contacts in the control circuit. When the control circuit is opened, the coil is de-energized and the main contacts open. The overload device is sensitive to current and time. Small over current conditions take longer to open the contacts than do large over current conditions. The overload device should not interrupt normal starting over currents or over current fluctuations that are too short to pose an overheating problem in the motor.



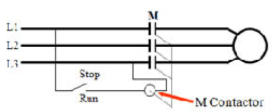
DASH-POT MAGNETIC

Another common type of inverse time overload device is the dash-pot magnetic relay. The dash-pot may be pneumatic or oil-filled. The motor current flows through a few turns of a coil, creating a magnetic field. That field tends to lift a plunger to a point where it opens a set of contacts connected to a dash-pot. Normal currents will not lift the plunger high enough to open the trip contacts. Over currents will lift the plunger high enough to open the trip contacts but the plungers action is retarded by the dash-pot. The greater the overload, the quicker the plunger overcomes the dash-pot resistance.

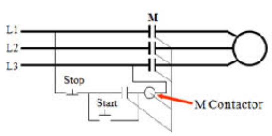
LOW VOLTAGE DAMAGE

Low Voltage Damage (1)

Another concern for motors is low voltage. Low voltage can cause motors to overheat which damages the insulation on the windings and can cause connection points to fail. For this reason, motor controllers must provide protection from low voltage.



LVR

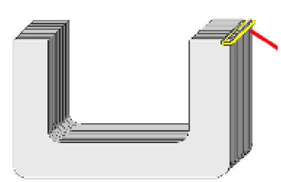


LVP

Low Voltage Devices (2)

Low voltage protection is achieved in two controller configurations: Low Voltage Release (LVR) and Low Voltage Protection (LVP). LVR controllers have voltage sensitive relays or devices that drop out at a preset under-voltage condition. LVP controllers add momentary pushbuttons and a holding contact to the under-voltage relay. This addition ensures that, once the relay drops out the line voltage, it will not automatically restart, as will the LVR configuration. In that NCC considers it unsafe to have crane functions that automatically restart, all new crane controls, and all crane controls that have undergone extensive alteration or replacement, shall be of the LVP type.

ARMATURE CHATTER



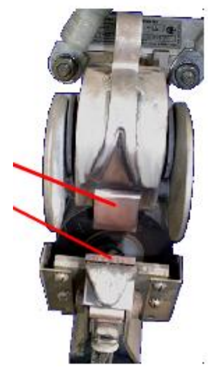
Another controller problem to anticipate is armature chatter. The current through the electromagnet varies from zero to maximum twice for every cycle. Since the pull is proportional to the current, the armature starts to drop out every time the current nears zero. Just enough movement takes place to cause “chatter”. To prevent chattering, a shading coil is installed around part of the pole face. The voltage induced into the shading coil causes a current that produces a magnetic field just strong enough to prevent chattering.

Environment for Contacts

Atmospheric conditions can have adverse effects on electrical contacts. Dust and corrosion produce high contact resistance. The resistance increases with time until eventually it reduces the current to a value that is too low for proper operation. To prevent dust accumulation, the starters should be cleaned with a high-power vacuum cleaner. Compressed air is sometimes used to blow away any dust. However, compressed air contains moisture, which may cause other problems. After the dust is removed from the starter, the contacts should be cleaned with a nontoxic cleaning agent. When using cleaning agents, always follow the directions supplied by the manufacturer. If, after a thorough cleaning, the contact resistance is not reduced sufficiently, the contacts should be replaced.

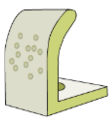
Contact Construction and Care

Contactors consist of a body, a coil, an armature, fixed contacts and movable contacts with their shunts. These contacts, consisting of a fixed contact and a movable contact, are designed to withstand the arcing characteristic of interrupting the large currents in the motor circuits they control. For this reason, they are replaceable and serviceable. They are mostly copper with some type of plating, usually silver. The silver is a good conductor and is softer than the copper, which allows it to conform to the mating surface. More importantly, the silver oxide that forms on the mating surface is also a good conductor whereas the cupric oxide that forms on the surface of a non-plated contact is a poor conductor. After a short time, even new contacts will blow most of the silver out of the mating surface. The bare copper that remains is still serviceable if the mating surface is kept clean and true to each other.

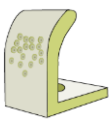


Dressing Contacts

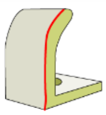
Dressing contacts is the maintenance technique that restores the mating surface of the contacts and addresses four areas of concern.



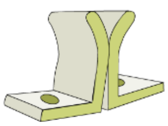
The raised blemishes on the surfaces are commonly called slag. Silver, being softer and having a lower melting temperature than the copper base, form small molten plasma balls during arcing and are usually thrown clear of the mating surface. Sometimes, the molten balls fall back into the gap and are captured by the contacts, forming raised surface blemishes. They interfere with the quality of the mating surfaces, are best removed with a fine file and can usually be worked in place.



Pits are where parts of the surface are missing. They do not pose a problem until they take up too much of the contact area. Because of the amount of material to remove and concern for shape, this maintenance is best done with the contacts removed.



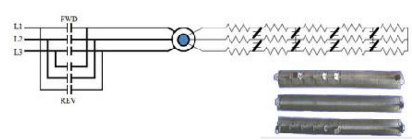
The shape of the mating surface is an important factor in how well the contactor breaks a current. The mating surface should be rounded so that when the contactor is slowly relaxed from the fully closed position, the movable contact cleanly wipes across the face of the fixed contact. Reshaping the surface is best done with the contacts removed.

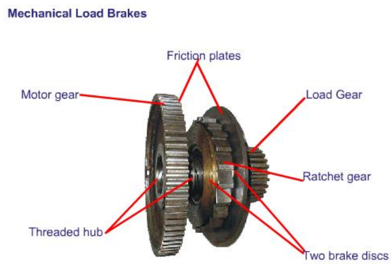


Contact alignment is achieved by adjusting the movable contact so that it strikes in the middle of the fixed contact and is in full contact across its face.

Wound Rotor Controllers

Controllers for wound-rotor induction motors have two sections, one for the stator and one for the rotor. The stator portion is an across-the-line starter with contactors to provide forward and reverse rotating fields. The rotor portion connects external resistor grids to the wound rotor circuit. At the start, all the resistance is connected to the rotor circuit and the stator is energized. As different speeds are selected on the master switch, the controller reduces the amount of resistance in the rotor circuit by changing the connection to the grid taps. This increases the rotor current and the motor torque. At full load hoist, the changes in motor torque provide different speed points. At no-load hoist, the reduced torque of the lower speed points is sufficient to bring the hoist to full speed.

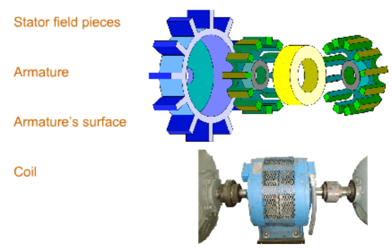




MECHANICAL LOAD BRAKES

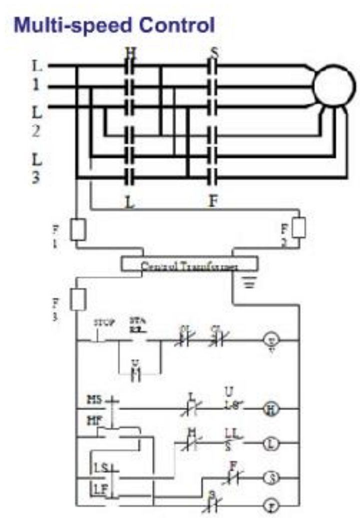
To compensate for the tendency to overhaul in lower speed points, wound rotor hoist systems employ electrical or mechanical load brakes. Mechanical load brakes consist of a load gear connected through a threaded hub to a motor gear, capturing a ratchet gear and two brake discs between the friction plates, all mounted in a gear box and submersed in lubricating oil. The weight of the load tends to screw the load gear onto the motor gear. Pawls engage the teeth of the ratchet gear and hold it stationary. The load is supported by the ratchet gear. To lower the load, the motor gear is driven in the lower direction which tends to unscrew the motor gear from the load gear. This removes some tension from the brake discs and the load is allowed to lower.

EDDY CURRENT BRAKES



The eddy current brake is the electrical approach to a load brake. The eddy current brake is a cast armature with integral cooling fans. As the rotor and stator field pieces rotate, they form alternating pole polarities near the rotor surface. The stator coil fits between the field pieces and magnetizes all the poles. The eddy current brake is mounted on the motor shaft. When DC current is applied to the brake coil, the resulting field retards the rotation of the shaft. The energy removed from the shaft is converted to heat by the eddy currents circulating in the armature. Since the brake torque is proportional to the speed, an eddy current brake will not stop a lowering hoist. Because the brake does not rely on friction, there is no wear or adjustment. The amount of braking torque is proportional to current. The eddy current brake lends itself to step-less controls where the controller regulates the current to the brake.

MULTI-SPEED CONTROL

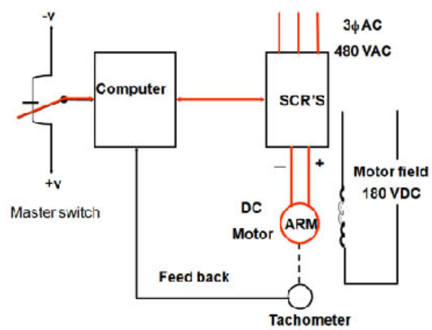


Multi-speed control of squirrel-cage motors can be obtained through push-button stations and magnetic relays. The controller is designed to change the external connections of the motor to obtain the various speeds. Drum controllers are sometimes used with medium and small sized motors to obtain speed control.

Controller Example: Hoist Function - Closed Loop Circuit

The master switch potentiometer provides a plus or minus reference voltage to the computer controller which determines direction of movement and speed. The computer controller (logic) receives this reference signal (input) and gates the silicon controlled rectifiers (SCRs) to convert and/or rectify the three-phase 480 volts AC to a constant potential DC voltage of 460 volts to supply to the motor armature. The motor armature turns when voltage is applied. The motor field is separately excited and constant. Armature voltage polarity is changed by the computer to determine direction of motor rotation.

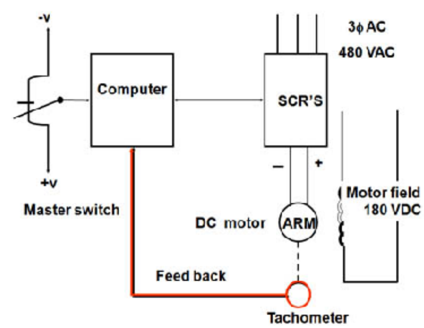
Controller Example: Hoist Function - Closed Loop Circuit

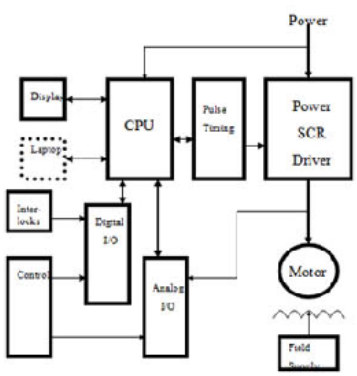


Basic Description of Operation (Hoist-Closed Loop)

(Hoist - Closed Loop) The tachometer, which is a small AC generator (permanent magnet), provides a voltage feedback to the computer controller. The tachometer is mechanically coupled to the motor shaft. The greater the shaft speed, the greater the voltage out of the tachometer. This feedback voltage is converted to a number and compared to the master switch reference in the computer. If the tachometer feedback is low, the computer controller adjusts the SCR gating to increase armature voltage, increase motor speed and increase tachometer output to match the master switch reference.

Basic Description of Operation (Hoist - Closed Loop)





Programmable Logic Controllers

Programmable Logic Controllers (1)

A programmable logic controller (PLC) is a special type of computer. It is designed to perform specific control functions in a logical order. The PLC is designed to be operated in an industrial environment. A PLC, like any computer, is programmed in binary. A PLC reads and converts parameters, provides control outputs, operates motor drivers, and operates in many modes with little or no human interface. PLC manufacturers have developed special programming aids that are styled after the contact logic common to controller design. This convention is called ladder logic in that series contacts are in horizontal groups forming the rungs and parallel contacts are in vertical groups forming the legs.

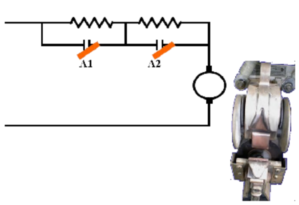
Programmable Logic Controller (2)

PLCs can be divided into five basic parts. The power supply is used to lower the incoming AC voltage to the desired level, rectify it to DC, and then filter and regulate it. The internal logic circuits of a PLC operate on five to fifteen volts DC, depending on the type of controller. The CPU is the brain of the PLC. It contains the microprocessor chip and related circuits to perform all the logic functions. The programming, or loading terminal, is a device used to program the CPU. One such device is a small key-pad and display, which may be hand held or panel mounted. The other type of terminal is a personal computer with port-to-port communications software. The I/O track is used to connect the CPU to the outside world. It contains input modules that carry information to the CPU and output modules that carry information from the CPU. The driver section contains the electronics that convert the line power into variable, reversible DC or variable frequency AC.

TROUBLESHOOTING CONTROLLERS

Troubleshooting DC Controllers (1)

Contactors or motor starters are the first device checked when troubleshooting a circuit that does not work or has a problem. They are checked first because they are the point where the incoming power, load, and control circuit are connected. Control devices use mechanical or solid-state switches to control the flow of current. A mechanical switch is any switch that uses contacts to start and stop the flow of current in a circuit. Contacts can be used to switch either AC or DC loads. A solid-state switch has no moving parts (contacts).



Troubleshooting DC Controllers (2)

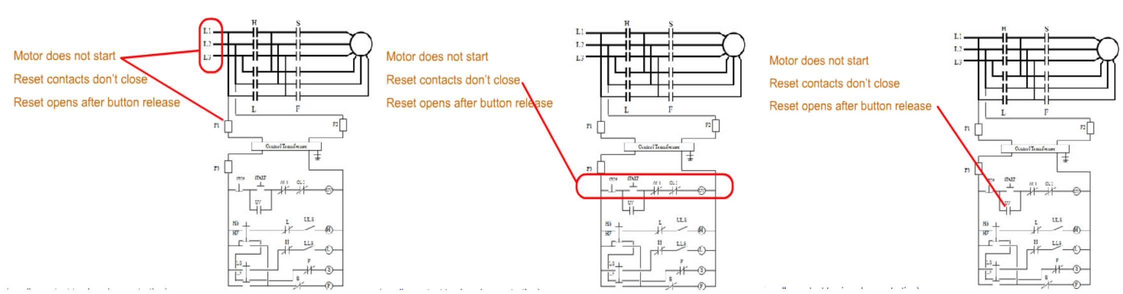
The following basic checks should be made when troubleshooting DC controllers.

- If the motor does not start when the handle is moved several points check the fuses, circuit breakers and relays.
- Check for an open resistor tap.
- Check the contacts on overloads and the controller contacts for low voltage.
- If the motor does not move through all speed points check for an open coil, low voltage, shorted circuit, overload failure, and/or the condition of the relay contacts.

Troubleshooting AC Controllers (1)

For a failure in AC controllers check the following.

- If the motor does not start when the handle is moved several points check the fuses, circuit breakers and main contacts.
- Check for an open resistor tap.
- Check the contacts on overloads. If the reset contacts don't close check for an open coil, low voltage, shorted coil, open overload relay, and/or dirty reset contacts. If the reset opens when button is released, check dirty maintaining contacts and station wiring.



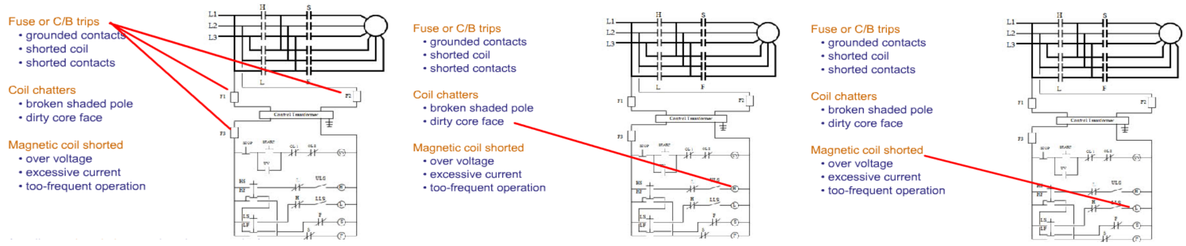
Additional AC Checks

Some additional checks for AC controllers include:

- If a fuse or circuit breaker trips when reset, check for grounded contacts, a shorted coil or shorted contacts.

- If the coil chatters, check for a broken shaded pole or a dirty core face.

- If the magnet coil is burned or shorted, check for over voltage, excessive current or too-frequent operation.



REVIEW AND SUMMARY

The Controllers module described the proper maintenance, repair and troubleshooting of controllers.

NOTES

Controllers Knowledge Check

Online questions may appear in a different order that those shown below.

1. True or False

There is no CEMF when the armature is stationary.

A. True
B. False

2. Select the best answer.

Select the item(s) from the list below that best describes the device(s) that connects and/or regulates the electrical power supplied to a component.

A. none of the listed items
B. controller
C. governor
D. calibrator

3. Select all that apply.

Select the item(s) from the list below that is/are not a type of controller discussed in this lesson.

A. limiting
B. sensory
C. all of the listed items are controllers
D. magnetic
E. solid state

4. True or False

In an induction motor, connections are made directly across the line because it will develop a higher starting torque than if it is started with a reduced voltage. This provides rapid acceleration to rated speed and permits starting under load. The starting current, however, will range from 4 to 6 times the full-load current.

A. True
B. False

5. Select the best answer.

Low voltages can cause motors to overheat which damages the insulation on the ________ and can cause connection points to fail.

A. stator
B. windings
C. brushes and rigging
D. commutator

6. Select all that apply.
Many factors must be considered when selecting starting equipment. These factors include:

A. motor protection
B. voltage line drop
C. starting current
D. type of load
E. none of the listed items

7. True or False
The overload device should not interrupt normal starting over currents or over current fluctuations that are too short to pose an overheating problem in the motor.

A. True
B. False

8. Select the best answer.
Normal currents ________ the plunger high enough to open the trip contacts. Over currents ________ the plunger high enough to open the trip contacts.

A. will not lift, will lift
B. will force, will retard
C. will turn, will return
D. will lift, will not lift

9. Select all that apply.
Over current protection falls into two general categories, they are:

A. voltage cycle depression
B. none of the items listed
C. all of the items listed
D. short-circuit/ground fault protection
E. overload protection

10. Select the best answer.
To prevent armature chatter, a ________ is installed around part of the pole face. The voltage induced into the shading coil causes a current that produces a magnetic field produced in this manner is just strong enough to prevent chattering.

A. pole face plate
B. chatter rectifier
C. shading coil
D. magnetic field dampener

11. Select all that apply.
Contactors contain the following parts/components:
A. rectifier
B. none of the listed items
C. shunts
D. all of the listed items
E. armature
F. coil

12. True or False
Contact alignment is achieved by adjusting the movable contact so that it strikes in the middle of the fixed contact and is in full contact across its face.

A. True
B. False

13. Select the best answer.
In a closed loop hoist, the ________ provides a plus (+) or minus (–) reference voltage to the computer controller which determines direction of movement and speed.

A. master switch potentiometer
B. tachometer output
C. silicon controlled rectifier
D. armature voltage polarity

14. Select the best answer.
What is the definition of a PLC?

A. Probably link causation relates the amount of negative shunt resistance to inverse voltage regulation.
B. A positive lead contact forms a resistance base in which the commutator can be methodically tested.
C. Predictable load current is the determination of output minus the resultant total force derived from diode bleed-off.
D. A programmable logic controller is a special type of computer the performs specific control functions in a logical order.

15. Select all that apply.
Select the item(s) from the list below that is/are considered the “brain(s)” of a PLC.

A. I/O track
B. power supply
C. logic circuits
D. driver
E. CPU

16. True or False
Contactors or motor starters are the not the first device checked when troubleshooting a circuit that does not work. They are not checked first because they are the point where the incoming power, load, and control circuit are connected.

A. True
B. False

17. Select all that apply.
The following basic checks should be made when troubleshooting DC controllers:

A. check the fuses, circuit breakers and relays
B. check for an open resistor tap
C. check the contacts on overloads and the controller contacts for low voltage
D. check for an open coil, low voltage, shorted circuit, overload failure, and/or the condition of the relay contacts
E. none of the listed items

NEC 1: ARTICLES 610.1-610.14

LEARNING OBJECTIVES

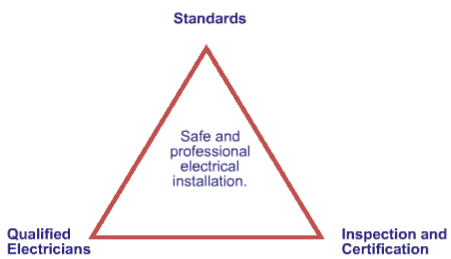
National Electrical Code Module 1 introduces the National Electrical Code (NEC) in general and Articles 610.1 through 610.14 in particular. Upon successful completion of this module you will be able to:

- understand the relationship between NEC, Navy Crane Center (NCC), and Navy crane work

- understand specific Article 610 requirements such as resistors, wiring methods, terminal fittings, conductor types and sizing, ampacities and temperature corrections

NATIONAL ELECTRICAL CODE

The purpose of NEC is the practical safeguarding of persons and property from hazards arising from the use of electricity. NEC is a set of standards for safe electrical installations but is not intended to be a design specification or an instruction manual for untrained persons. The "authority-having-jurisdiction" sets the standards for installation, which in the case of Navy owned cranes is NCC. NAVFAC P307, along with other standard setting organizations like NEC, sets standards for maintenance, inspection and certification work on Navy owned cranes. Qualified persons, or more precisely, qualified electrical workers, have the responsibility to provide "safe and professional electrical installations". Combining safe standards, qualified persons, and approved inspection and certification processes results in safe and professional electrical installations.



NAVY CRANE CENTER INVOKES NEC

Article 610 of the NEC applies to cranes and hoists and is the basis for this and the following two modules. It is not the intent of this introductory level course to present an in-depth study of the entire NEC. This course will:

- provide an NEC overview that will aid the crane maintenance electrician in identifying work that is required to be in compliance with NEC standards
- familiarize the electrician with the location of Articles that can provide guidance for crane related work
- introduce various calculations, of which, crane electricians should be aware

In addition to Article 610, there are other articles in NEC that are often used in the performance of electrical maintenance on cranes.

Additionally, knowledge of various NEC tables is necessary to meet the needs of electricians assigned to work on cranes.

ARTICLE 610.1 SCOPE

NEC Article 610 covers the installation of electrical equipment and wiring used in connection with many types of cranes, monorails, hoists, and all runways. NEC does not apply to mobile cranes and locomotive cranes.

This section references the B30 standard which is published by the American National Standards Institute, or ANSI and the American Society of Mechanical Engineers, or ASME. The B30 standard provides guidance, definitions, common nomenclature, and design specifications, etc., for the covered types of weight handling equipment. It does not address the technical aspects of cable and electrical equipment installation

Electrical maintenance personnel are not usually called on to use the guidance provided by ASME B-30.

ARTICLE 610.3(A) SPECIAL REQUIREMENTS

Article 610.3(A) Special Requirements

Hazardous (Classified) Locations, states that all equipment that operates in a hazardous (classified) location shall conform to article 500. Article 501, Class I Locations, covers equipment used in locations that have flammable gases or vapors present. Article 502, Class II Locations, covers equipment used in locations that have combustible dust present. Article 503, Class III Locations, covers equipment used in locations that have easily ignitable fibers or flyings present.

For more details on equipment in Class III locations, see the commentary following Article 503.155(D).

When you are assigned work on cranes or hoists in hazardous locations, as defined in article 500, you should refresh your understanding of the applicable article(s). You need to have the ability and knowledge to recognize and report existing installations or hazards that are not in compliance with NEC. This will aid your organization or activity in identifying and evaluating potentially unsafe and/or non-compliant concerns.

Article 610.3(B) Resistors

Combustible Materials: Where a crane, hoist, or monorail hoist operates over readily combustible material, the resistors shall be located in the following:

(1) A well-ventilated cabinet composed of noncombustible material and constructed so that it will not emit flames or molten metal.
(2) In a cage or cab constructed of noncombustible material that encloses the sides of the cage or cab from the floor to a point at least 6 inches above the top of the resistors.

ARTICLE 610.11 WIRING METHODS

All Cranes shall have all electrical conductors enclosed in raceways except: Type AC (Armored Cable), MC (Metal Clad), or MI (Mineral Insulated Metal Sheath) cable.

Exceptions to this rule include: (A) contact conductors; (B) short lengths of exposed conductors at resistors, collectors and other equipment, (C) flexible connections to motors and similar equipment, (D) pushbutton station multi-conductor cable, (E) where flexibility is required for power or control to moving parts, listed festoon cable or cord suitable for the purpose shall be permitted, provided the following apply:

(1) Suitable strain relief and protection from physical damage is provided.

(2) In Class I, Division 2 location, the cord is approved for extra-hard usage.

Note: Navy Crane Center requires that raceways be ferrous rigid metal conduit; where flexible connections are necessary, liquid-tight flexible metal conduit shall be use.

ARTICLE 610.12 TERMINAL FITTINGS

Conductors leaving raceways, or cables, shall comply with one of the following:

A) A box or terminal fitting that has a separately bushed hole for each conductor shall be used wherever a change is made from a raceway or cable to exposed wiring. A fitting used for this purpose shall not contain taps or splices and shall not be used at fixture outlets.
B) A bushing shall be permitted to be used in lieu of a box at the end of a rigid metal conduit, intermediate metal conduit, or electrical metallic tubing where the raceway terminates at unenclosed controls or similar equipment, including contact conductors, collectors, resistors, brakes, power-circuit limit switches, and DC split-frame motors.

ARTICLE 610.13 TYPES OF CONDUCTORS

Conductors shall comply with Table 310.104(A) unless otherwise permitted in Article 610.13(A) through (D) with the following exceptions:

(A) Conductors exposed to external heat, or connected to resistors shall have a flame-resistant outer covering or flame-resistant tape.
(B) Contact conductors along runways, crane bridges, and monorails shall be permitted to be bare, and shall be copper, aluminum, steel or other alloys or combinations thereof in the form of hard drawn wires.
(C) Where flexibility is required, flexible cord or cable shall be permitted to be used (see Article 400.7(A)).
(D) Conductors for Class 1, Class 2, and Class 3 remote-control, signaling, and power limited circuits, installed in accordance with Article 725, shall be permitted.

Note: Unless otherwise specified, Navy Crane Center requires interconnecting wiring to be of copper stranded construction complying with Table 310.104 of NFPA 70. Aluminum conductors shall not be used. Aluminum connectors are allowed if they are rated for use with copper conductors.

ARTICLE 610.14 RATING AND SIZE OF CONDUCTOR

Table 610.14 Rating and Size of Conductor

Article 610.14 (A – G) deals with the rating and size of conductors. Table 610.14(A) gives the allowable ampacities of conductors used on cranes and hoists. Conductors used to connect controllers to separately mounted resistors shall be sized by multiplying the motor's secondary (rotor) current by the appropriate demand factor from Table 610.14(B) and then selecting the proper sized conductor from Table 610.14(A). Conductors external from motors and controllers shall not be smaller than #16 AWG, with two exceptions.

(1) #18 AWG multi-conductor cable permitted for control circuits not over 7 amps.
(2) #20 AWG permitted for electronic circuits.

Contact conductors (collectors) shall be sized for 75º Celsius wire from Table 610.14(A). The table in this section gives additional requirements for sizing contact conductors based on the distance between supports.

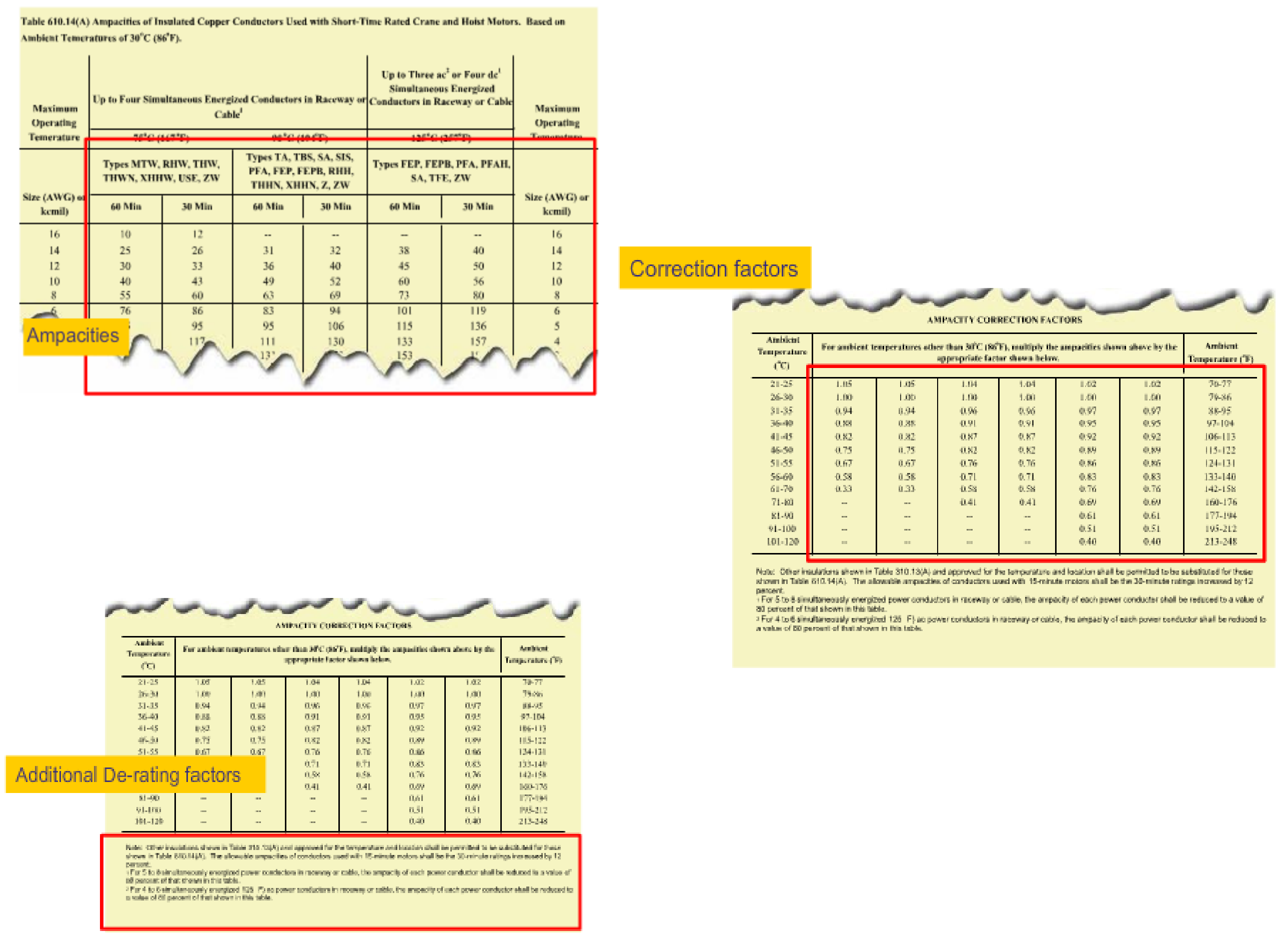
Sections (E) and (F) deal with the calculation of motor loads and other loads.

Section (G) requires name plate information on cranes, monorails, and hoists.

Note: Navy Crane Center requires that motor branch circuit conductors be sized as to have an ampacity not less than 150 percent of the motor full load current rating and to be no smaller than 12 AWG. In determining the ampacity of continuous loads such as utility, heating, lighting, and air conditioning shall be multiplied by 2.25 in order to permit application of NEC 610.14(A) for crane supply conductors.

(A) Layout

Table 610.14(A) organizes cable installation data into several sections. Ampacities for several common conductor types are listed for three operating temperatures and two duty cycles. Correction factors for ambient temperatures are given for each type and rating. Additional de-rating factors are given for 15-minute rating, 5 to 8 simultaneously energized conductors, and 4 to 6 simultaneously energized 125°Celsius AC power conductors.



AMPACITY CORRECTION FACTORS

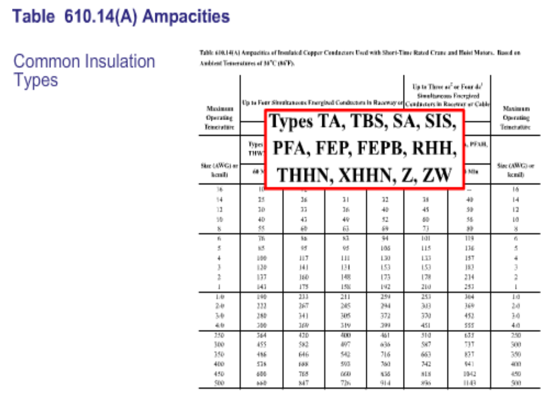
Ambient Temperature (°C)	For ambient temperatures other than 30°C (86°F), multiply the ampacities shown above by the appropriate factor shown below.						Ambient Temperature (°F)
21-25	1.05	1.05	1.04	1.04	1.02	1.02	70-77
26-30	1.00	1.00	1.00	1.00	1.00	1.00	79-86
31-35	0.94	0.94	0.96	0.96	0.97	0.97	88-95
36-40	0.88	0.88	0.91	0.91	0.95	0.95	97-104
41-45	0.82	0.82	0.87	0.87	0.92	0.92	106-113
46-50	0.75	0.75	0.82	0.82	0.89	0.89	115-122
51-55	0.67	0.67	0.76	0.76	0.86	0.86	124-131
56-60	0.58	0.58	0.71	0.71	0.83	0.83	133-140
61-70	0.33	0.33	0.58	0.58	0.76	0.76	142-158
71-80	--	--	0.41	0.41	0.69	0.69	160-176
81-90	--	--	--	--	0.61	0.61	177-194
91-100	--	--	--	--	0.51	0.51	195-212
101-120	--	--	--	--	0.40	0.40	213-248

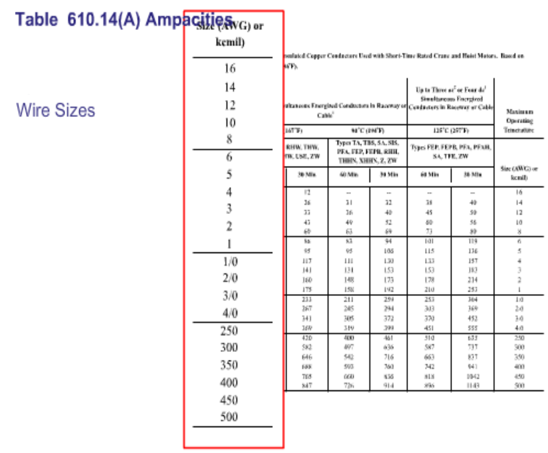
Maximum Operating Temperature	Up to Four Simultaneous Energized Conductors in Raceway or Cable[1]				Up to Three ac[2] or Four dc[1] Simultaneous Energized Conductors in Raceway or Cable		Maximum Operating Temperature
	75°C (167°F)		90°C (194°F)		125°C (257°F)		
	Types MTW, RHW, THW, THWN, XHHW, USE, ZW		Types TA, TBS, SA, SIS, PFA, FEP, FEPB, RHH, THHN, XHHN, Z, ZW		Types FEP, FEPB, PFA, PFAH, SA, TFE, ZW		
Size (AWG) or kcmil)	60 Min	30 Min	60 Min	30 Min	60 Min	30 Min	Size (AWG) or kcmil)
16	10	12	--	--	--	--	16
14	25	26	31	32	38	40	14
12	30	33	36	40	45	50	12
10	40	43	49	52	60	56	10
8	55	60	63	69	73	80	8
6	76	86	83	94	101	119	6
5	85	95	95	106	115	136	5
4	100	117	111	130	133	157	4
3	120	141	131	153	153	183	3
2	137	160	148	173	178	214	2
1	143	175	158	192	210	253	1
1/0	190		211	259	253	[illegible]	1/0

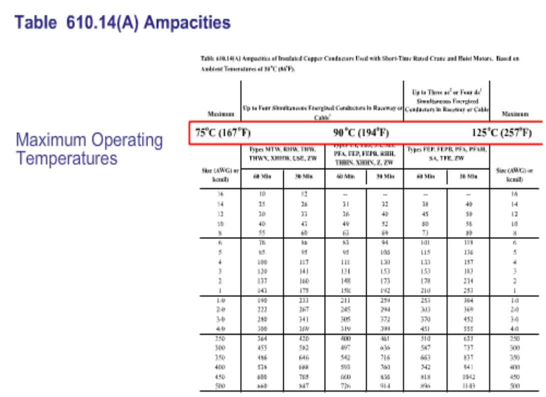
(A) Ampacities

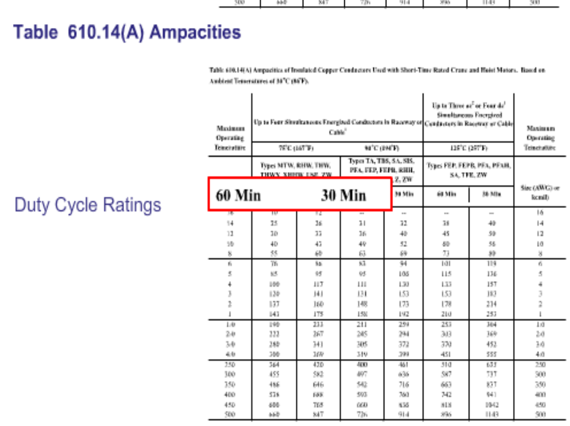
The Table 610.14(A) ampacity section is the starting point for choosing a wire type or size. The common insulation types are given for cranes. If other types of insulations are more appropriate for an application, the note at the foot of Table 610.14(A) refers to Table 310.104(A) for further guidance. Wire Sizes from #16 American Wire Gauge (AWG) to 500 Thousand Circular Mil (kcmil), are listed as those that are most commonly used on cranes. Most insulation types come with several different maximum operating temperatures. The more common ones are listed here. Few hoist motors are rated for Continuous Duty. They are, therefore, rated Intermittent Duty. Two of the more common Duty Cycle Ratings are 60 min. and 30 min. A motors design duty cycle can be found on the motor name plate, on the appropriate configuration blue print, or in the Crane Acceptance Package.

Note: The Crane Manufacturer's Association of America (CMAA) manual 70 Article 5.2.7 sets hoist motor ratings as described in Table 5.2.7-1. Navy Crane Center requires that all AC motors have a 60-minute duty rating, minimum. CMAA 70-5.2.7 sets minimum motor rating based on type of controls used.









(A) Temperature Correction

The Table 610.14(A) ampacity correction factors correct the ampacities for ambient temperatures other than 30°Celsius (or 86° Fahrenheit). The ampacity of a conductor is affected by the conductor's ability to cool itself by giving up heat to the surroundings at ambient temperature. The higher the ambient temperature, the less heat that is transferred. Conductors operating in higher temperatures have to be de-rated by multiplying the standard ampacity by the appropriate factor. Those correction factors are listed for the three types and duty cycle columns for both Fahrenheit and Celsius.

AMPACITY CORRECTION FACTORS

Ambient Temperature (°C)	For ambient temperatures other than 30°C (86°F), multiply the ampacities shown above by the appropriate factor shown below.						Ambient Temperature (°F)
21-25	1.05	1.05	1.04	1.04	1.02	1.02	70-77
26-30	1.00	1.00	1.00	1.00	1.00	1.00	79-86
31-35	0.94	0.94	0.96	0.96	0.97	0.97	88-95
36-40	0.88	0.88	0.91	0.91	0.95	0.95	97-104
41-45	0.82	0.82	0.87	0.87	0.92	0.92	106-113
46-50	0.75	0.75	0.82	0.82	0.89	0.89	115-122
51-55	0.67	0.67	0.76	0.76	0.86	0.86	124-131
56-60	0.58	0.58	0.71	0.71	0.83	0.83	133-140
61-70	0.33	0.33	0.58	0.58	0.76	0.76	142-158
71-80	—	—	0.41	0.41	0.69	0.69	160-176
81-90	—	—	—	—	0.61	0.61	177-194
91-100	—	—	—	—	0.51	0.51	195-212
101-120	—	—	—	—	0.40	0.40	213-248

(A) Notes

In addition to referring to the insulation types in Table 310.104(A), the Table 610.14(A) notes section provides additional factors. The notes section requires ampacities of conductors used with 15-minute duty cycle motors to be the same rating as 30-minute duty cycle motors, increased by 12 percent.

For direct current with 5 to 8 simultaneously energized power conductors in a raceway or cable, shall have a reduced ampacity of 80 percent.

For alternating current with 4 to 6 simultaneous energized conductors in a raceway or cable, shall also be reduced by 80 percent.

Summary and Review

This module presented the National Electrical Code (NEC) in general and Articles 610.1 through 610.14 in particular. You should now understand the relationship between NEC, Navy Crane Center, and Navy crane work. You learned about specific Article 610 requirements such as: resistors, wiring methods, terminal fittings, conductor types and sizing, ampacities, and temperature corrections.

NOTES

NEC Module 1 Knowledge Check

Online questions may appear in a different order that those shown below.

1. Select the best answer.

What NEC Article covers cranes and hoists?

A. Article 610
B. Article 450
C. Article 300
D. Article 100

2. True or False

Short lengths of exposed conductors may be installed at resistors, collectors, and other equipment.

A. True
B. False

3. Select the best answer.

Where will the resistors be located on a crane or hoist which operates over readily combustible material?

A. A well ventilated cabinet
B. A cage constructed of combustible material
C. In a bushed box of metal construction
D. On the supporting column or beam

4. Select the best answer.

All cranes shall have all electrical conductors enclosed in race ways except for:

A. Types AC, MC, and MI
B. Types UHF, PFD, and PDA
C. Types NFL, SIS, and CPU
D. Types UF, RHH, and Z

5. True or False

Bushings may be used in lieu of boxes at the end of liquid-tight flexible non-metallic conduit where the raceway terminates at unenclosed controls or similar equipment.

A. True
B. False

6. Select all that apply.
Select the type(s) of materials from the below list that are permitted to be used as contact conductors.

A. copper
B. nickel
C. steel
D. brass
E. aluminum
F. hard-drawn plastic

7. Select the best answer.
What NEC Table is the starting point for choosing wire type and size?

A. Table 610.14(A)
B. Table C4
C. Table 310.18
D. Table 610.14(E)

NEC 2: ARTICLES 610.15 – 610.51, 430, and 470

LEARNING OBJECTIVES

In this module, you will be introduced to various aspects of the NEC beginning with Article 610.15 and ending Article 610.51. You will be exposed to requirements for the use of common returns, contact conductors, and collectors. Disconnecting means will be covered and include location, accessibility, and rating information for different applications. Overcurrent and overload protection will be discussed and present requirements for feeders, runway conductors, branch circuits, taps, motors, control circuits, fuse and breaker ratings, single and multiple motor configurations and various exceptions. Article 430 will be referenced to show cycle duties and ratings for ampacities for secondary currents. Finally, Article 470 will introduce resistors and reactors and the requirements for their use.

ARTICLE 610.15 COMMON RETURN

Article 610.15, Common Return: Where a crane or hoist is operated by more than one motor, a common-return conductor of proper ampacity shall be permitted.

ARTICLE 610.21 CONTACT CONDUCTORS

Article 610.21 Contact Conductors

Contact conductors shall comply with 610.21(A) through (H).

(A) Runway contact conductors shall be guarded, and bridge conductors shall be located or guarded in such a manner that persons cannot inadvertently touch energized current-carrying parts.

(B) Wires that are used as contact conductors shall be secured at the ends by means of approved strain insulators and shall be mounted on approved insulators so that the extreme limit of displacement of the wired does not bring the latter within less than one and a half inch from the surface wired over.

(C) Main contact conductors carried along runways shall be supported on insulating supports placed at intervals not exceeding twenty feet unless otherwise permitted in 610.21(F). Such conductors shall be separated at not less than six inches, other than for monorail hoists where a spacing of not less than three inches shall be permitted. Where necessary, intervals between insulating supports shall be permitted to be increased up to forty feet, the separation between conductors being increased proportionately.

(D) Bridge wire contact conductors shall be kept at least two and a half inches apart, and, where the span exceeds eighty feet, insulating saddles shall be placed at intervals not exceeding fifty feet.

(E) Conductors along runways and crane bridges, that are of the rigid type specified in 610.13(B) and not contained within an approved enclosed assembly, shall be carried on insulating supports spaced at intervals of not more than 80 times the vertical dimension of the conductor, but in no case greater that fifteen feet, and spaced apart sufficiently to give a clear electrical separation of conductors or adjacent collectors of not less than one inch.

(F) Monorail, tram rail, or crane runway tracks shall be permitted as a conductor of current for one phase of a 3-phase, AC system furnishing power to the carrier, crane, or trolley, provided all of the following conditions are met:
(1) The conductors supplying the other two phases of the power supply are insulated.
(2) The power for all phases is obtained from an insulating transformer.
(3) The voltage does not exceed 300 volts.
(4) The rail serving as a conductor shall be bonded to the equipment grounding conductor at the transformer and shall be permitted to be grounded by the fittings used for the suspension or attachment of the rail to a building or structure.

(G) All section of contact conductors shall be mechanically joined to provide a continuous electrical connection.

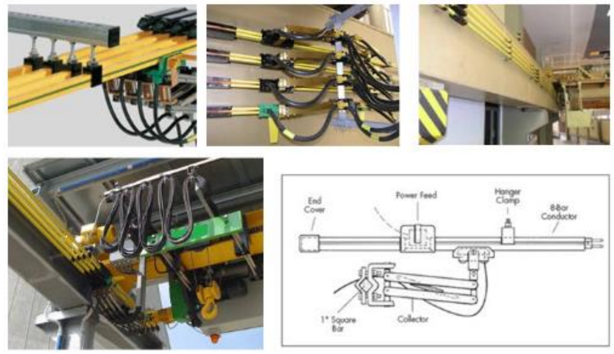
(H) Contact conductors shall not be used as feeders for any equipment other than the crane(s) or hoist(s) that they are primarily designed to serve.

Note: Navy Crane Center requires rigid conductors that consist of three power conductors and an equipment grounding conductor, and shall be enclosed safety-bar type.

Maintenance Considerations

While working in, on, and near energized parts may be "normal" work for qualified persons, it is not normal for other persons. Often times, during maintenance or service work, it is necessary to remove guards and access covers, exposing energized components. Lockout, tagout and energy isolation policies shall always be followed to mitigate these types of hazards. Other personnel shall be protected through the appropriate application of barricades, barriers, and safety signs to alert them of the hazards present. Replace guards and covers as soon as practical.

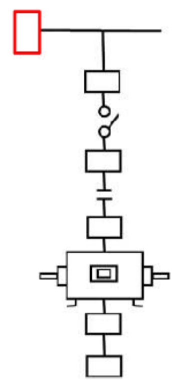
Section (H) Maintenance Considerations



Runway contact conductors shall not be used as feeders for any equipment other than the crane or hoist that it serves. Crane maintenance personnel, especially electricians, should be familiar with the location of the runway feeder connection point. Anytime it's discovered that additional circuits are connected to the runway contact conductors, these unauthorized circuits shall be reported and corrected.

Article 610.31 Runway Disconnect Means

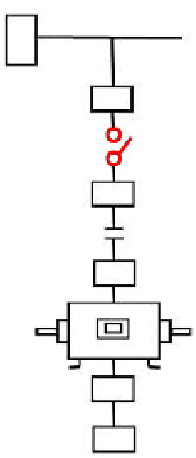
A means to disconnect, that has a continuous ampere rating, not less than that computed in Article 610.14 sections (E) and (F), shall be provided between the runway contact conductors and the power supply. The disconnecting means shall comply with Article 430.109.



This disconnecting means shall be as follows:

(1) Readily accessible and operable from the ground or floor level.
(2) Lockable open in accordance with Article 110.25.
(3) Open all ungrounded conductors simultaneously.
(4) Placed within view of the runway contact conductors.

See Article 610.31 for exceptions.



Article 610.32 Disconnection Means

A disconnecting means in compliance with article 430.109 shall be provided on the leads from the runway contact conductors or other power supply, on all cranes and monorail hoist. The disconnecting means shall be lockable in the open position accordance with article 110.25. Where monorail hoist or hand-propelled crane bridge installation meets all of the following, the disconnecting means shall be permitted to be omitted: (1) The unit is controlled from the ground or floor level. (2) The unit is within view of the power supply disconnecting means. (3) No fixed work platform has been provided for servicing the unit.

Where the disconnecting means is not readily accessible from the crane or monorail hoist operating station, means shall be provided at the operating station to open the power circuit to all motors of the crane or monorail hoist.

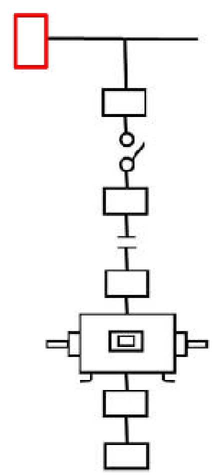
Note: Navy Crane Center requires that on bridge cranes a circuit breaker is to be used as the disconnecting means on the crane. It is selected based upon the load it is supplying and is sized to protect the feeders. A fused disconnect switch may also be used for this function. It is fed by the leads from the runway electrification system; the runway electrification system is protected by equipment in the building. On portal, floating, and container cranes, the feeder supplied by the generator is protected by a circuit breaker. It is selected based upon the load it is supplying. This breaker also protects the generator itself.

ARTICLE 610.33 DISCONNECT RATING

The continuous ampere rating of the switch or circuit breaker required by 610.32 shall not be less than 50 percent of the combined short-time ampere rating of the motors or less than 75 percent of the sum of the short-time ampere rating of the motors required for any single motion.

During inspections, check the leads, connection devices, and other conductors associated with the device for overheating. Discolored conductors and connectors, melted or cracking insulation or a distinctive smell of overheated insulation are all indications that the device may be under-rated for the current. These types of indicators should be documented and reported to your supervisor and engineering for resolution.

Note: On bridge cranes, the disconnecting means is required by Navy Crane Center to be sized for simultaneous operation of bridge, trolley, and hoist drives.



ARTICLE 610.41 OVERCURRENT PROTECTION FOR FEEDER AND RUNWAY CONDUCTORS

For single feeders, the runway supply conductors and main contact conductors of a crane or monorail shall be protected by an overcurrent device(s) that shall not be greater than the largest rating or setting of any branch-circuit protective device plus the sum of the nameplate ratings of all the other loads with application of the demand factors from Table 610.14(E).

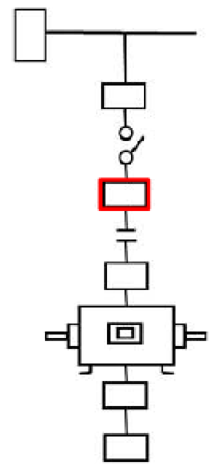
For multiple feeder circuits where more than one feeder circuit is installed to supply runway conductors, each feeder circuit shall be sized and protected in compliance with article 610.41(A).

Multiple feeders are sometimes used to supply long runway conductors to minimize voltage drops on the runway conductors.

As noted in Table 430.52, the ratings for overcurrent devices, listed as "Instantaneous Trip Breaker" are far greater than those listed as "Inverse Time Breakers". Such overcurrent devices are not subject to spontaneous trips. If an overcorrect device has tripped or is open, then a major fault has occurred, the device has malfunctioned, and/or the device is improperly rated for the circuit.

ARTICLE 610.42 BRANCH-CIRCUIT, SHORT-CIRCUIT AND GROUND-FAULT PROTECTION

Branch circuits shall be protected in accordance with 610.42(A). Branch-circuit taps, where made, shall comply with 610.42(B).



(A) Fuse or Circuit Breaker Rating.

Crane, hoist, and monorail hoist motor branch circuits shall be protected by fuses or inverse-time circuit breakers that have a rating in accordance with Table 430.52. Where two or more motors operate a single motion, the sum of their nameplate current ratings shall be considered as that of a single motor.

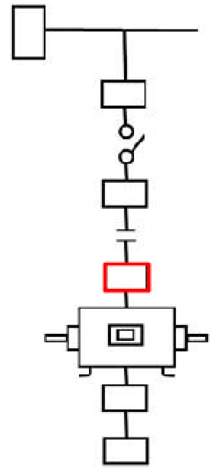
(B) Taps

(1) Multiple Motors. Where two or more motors are connected to the same branch circuit, each tap conductor to an individual motor shall have an ampacity not less than one-third that of the branch circuit. Each motor shall be protected from overload according to 610.43.

(2) Control Circuits. Where taps to control circuits originate on the load side of a branch-circuit protective device, each tap and piece of equipment shall be protected in accordance with 430.72.

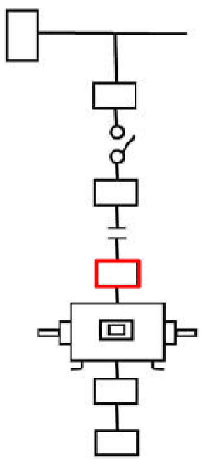
(3) Brake Coils. Taps without separate overcurrent protection shall be permitted to break coils.

ARTICLE 610.43 (1)



Article 610.43 Overload Protection

Overload Protection addresses the need to protect motors from the heat associated with an overload condition. A motor's rated horsepower is determined by the amount of current needed to raise the motor windings to the designed temperature. If the load on the motor is greater than rated load, the overload will cause the motor temperature to rise. That temperature rise is proportional to the amount of the overload and length of time the motor is overloaded. Motors can tolerate large overloads for short periods of time provided there is time to cool down between overloads. However, slight overloads over long periods can cause the motor temperature to rise to a point of doing damage to the windings. Current trip devices that react in a manner that reflects this relationship are called "inverse-time overloads". Article 610.43 provides related requirements as shown on the following five screens.



Motor Overload Devices

Several in-line devices provide the required overload protection. A heater element may be placed in each of the ungrounded motor leads. It heats the latching mechanism of the main contacts of a circuit breaker or the normally closed contacts of the motor contactor or control under-voltage relay. In this case, the heat build-up in the device simulates the heat build-up in the windings.

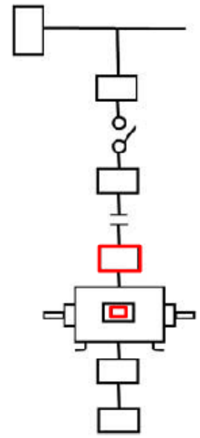
A series overload relay consists of a few turns of heavy conductor, a plunger that is drawn into the field created by coil, and a set of contacts that open the control circuit or trips the latch holding the line contacts of a breaker shut. If the movement of the plunger is restricted by a dash pot filled with viscous oil, this relay goes from instantaneous to inverse-time.

Electronic overloads take a signal from a series shunt in each ungrounded motor lead and provide both instantaneous and inverse-time sensing. The unit has a set of maintained contacts connected into the M contactor or under-voltage relay circuits.

These devices are addressed in greater detail in the controller module.

(A) Motor Overload Protection

Motor and Branch-Circuit Overload Protection states that each motor, motor controller and branch-circuit shall be protected from overload by one of the following means:



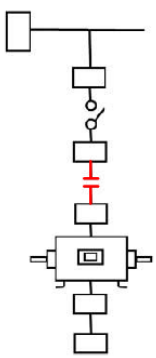
(1) A single motor shall be considered as protected where the branch-circuit overcurrent device meets the rating requirements of 610.42.

(2) Overload relay elements in each ungrounded circuit conductor, with all relay elements protected from short circuit by the branch-circuit protection.

(3) Thermal sensing devices, sensitive to motor temperature or to temperature and current, are in contact with the motor winding(s).

(4) A hoist or trolley shall be considered to be protected if the sensing device is connected in the hoist's upper limit switch circuit to prevent further hoisting during an overload condition of either motor.

Note: For crane motors, the use of an inverse-time overload relay or an electronic relay for AC motors is required by Navy Crane Center.



ARTICLE 610.43 (2)

Article 610.43 (B) Manually Controlled

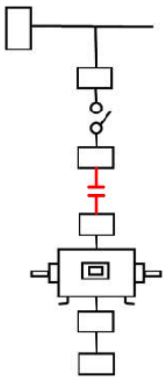
For manually controlled motors with spring return controls, Article 610.43 (B), Manually Controlled states that the overload protective device shall not be required to protect the motor against stalled rotor conditions.

(C) Multimotor

Where two or more motors drive a single trolley, truck, or bridge and are controlled as a unit and protected by a single set of overload devices with a rating equal to the sum of their rated full-load current, Article 610.43 (C), Multimotor, states that a hoist or trolley shall be considered to be protected if the sensing device is connected in the hoist's upper limit switch circuit so as to prevent further hoisting during an over-temperature condition of either motor.

(D) Hoist and Monorail Hoists

Article 610.43 (D) states that hoists and monorail hoists and their trolleys that are not used as part of an overhead traveling crane shall not require individual motor overload protection, provided the largest motor does not exceed seven-and-a-half horse-power and all motors are under manual control of the operator.



ARTICLE 610.51 MOTOR CONTROLS

Each motor shall be provided with an individual controller unless otherwise permitted in 610.51(A) or (B).

(A) Motions with More Than One Motor. Where two or more motors drive a single hoist, carriage, truck, or bridge, they shall be permitted to be controlled by a single controller.

(B) Multiple Motion Controller. One controller shall be permitted to be switched between motors, under the following conditions:

(1) The controller has a horsepower rating that is not lower that the horsepower rating of the largest motor.

(2) Only one motor is operated at one time.

ARTICLE 430.23 WOUND ROTOR SECONDARY

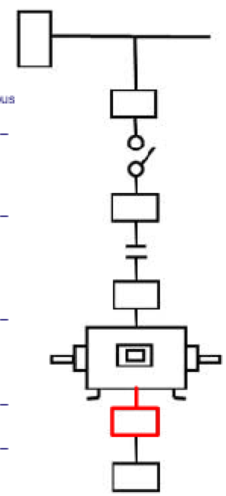
Most of the motors used on AC bridge cranes are wound rotor motors. The circuitry connected to that rotor is referred to as its "secondary". Article 430.23 addresses the ampacity of the secondary conductors for both continuous and non-continuous duty hoist motors. The article refers to Table 430.22(E) "Duty Cycle Service" and provides service classifications and current rating percentages.

Article 430.23 Wound Rotor Secondary

Table 430.22 (E) Duty Cycle Service

	Nameplate Current Rating Percentages			
Classification of Service	5-minute rated Motor	15-minute rated Motor	Minute Rated Motor	Continuous Rated Motor
Short-time duty operating valves, raising or lowering rolls, etc.	110	120	150	---
Intermittent duty Freight and passenger elevators, tool head, pumps, drawbridges, turntables, etc. (for arc welders, see 630.11)	85	85	90	140
Periodic duty rolls, ore- and coal handling machines, etc.	85	90	95	140
Varying duty	110	120	150	200

Note: Any motor application shall be considered as continuous duty unless the nature of the apparatus it drives is such that the motor will no operate continuously with load under an condition of use.



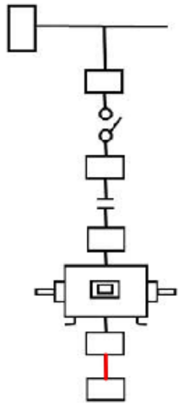
Consult your engineering organization with any questions regarding specific secondary current percentages and classifications. Article 430.23(B) states that for other-than-continuous-duty, conductors shall have an ampacity, in percent of full-load secondary current, not less than that specified in Table 430.22(E).

Note: Navy Crane Center requires a "60-minute rating minimum" for AC motors at 150 percent for "Varying Duty".

Article 430.23 (C) Resistor Separate from Controller

Table 430.23 (C) Secondary Controller

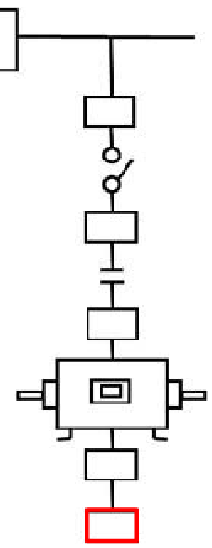
Resistor Duty Classification	Ampacity of Conductor in Percent of Full-Load Secondary Current
Light starting duty	35
Heavy starting duty	45
Extra-heavy starting duty	55
Light intermittent duty	65
Medium intermittent duty	75
Heavy intermittent duty	85
Continuous duty	110



ARTICLE 430.23 (C) RESISTOR SEPARATE FROM CONTROLLER

Where the secondary resistor is separate from the controller, the ampacity of the conductors between controller and resistor shall not be less that that shown in Table 430.23(C).

Consult your engineering organization with any questions regarding specific secondary current percentages and classifications.



ARTICLE 470 RESISTORS AND REACTORS

Article 470 covers the installation of separate resistors and reactors in electrical circuits. Article 470 is separated in two sections. Section one provides guidelines for resistor and reactor applications rated at six hundred nominal volts and under, while section two provides the same for applications over six hundred volts nominal.

470.2 - explains that resistors and reactors shall not be placed where exposed to physical damage.

470.3 - notes that a thermal barrier shall be required if the space between the resistors and reactors and any combustible material is less than twelve inches.

470.4 – goes on to explain that insulated conductors used for connections between resistance elements and controllers shall be suitable for an operating temperature of not less than 194 degrees Fahrenheit.

Note: Navy Crane Center requires that all conductors connected to or routed above resistors have, an insulation shown in NEC Table 610.14(A) for 257 degrees Fahrenheit; however, conductors having type FEPB insulation with an asbestos braid would not be permitted to be used. Although NEC Section 470.4 requires that conductors used for connections to resistors be rated for at least 194 degrees Fahrenheit, Navy Crane Center requires that those conductors be rated for 257 degrees Fahrenheit to ensure their longevity.

SUMMARY AND REVIEW

This module presented NEC Articles 610.15 through 610.43 (and 610.51). You were introduced to requirements for the use of common returns, contact conductors, and collectors. Disconnecting means was covered and included location, accessibility, and rating information for different applications. Overcurrent and overload protection was covered in-depth and provided insight on feeders, runway conductors, branch circuits, taps, motors, control circuits, fuse and breaker ratings, single and multiple motor configurations and various exceptions. Article 430 was referenced to show cycle duties and ratings for ampacities for secondary currents. Finally, Article 470 introduced resistors and reactors and requirements for their use. Also noted were several Navy Crane Center specifications that go above and beyond NEC code requirements.

NOTES

NEC Module 2 Knowledge Check

Online questions may appear in a different order that those shown below.

1. True or False

Wires used for contact conductors shall be mounted such that the extreme displacement of the wire does not come within one inch of the surface being wired over.

A. True
B. False

2. Select the best answer.

Runway contact conductors shall not be used as feeders for any equipment other than the crane, except for:

A. 440VAC milling machine
B. 110VAC office lighting
C. 220VDC building fan
D. there is no exception
E. A and B

3. Select all that apply.

A disconnecting means shall:

A. contain taps without separate overcurrent devices
B. be readily accessible
C. be within view of the runway contact conductors
D. be capable of being locked in the open position
E. contain at least two pushbutton switches
F. open all ungrounded conductors simultaneously

4. Select the best answer.

Crane, hoist, and monorail hoist motor branch circuits shall be protected by fuses or inverse-time circuit breakers. What article or table would you reference to determine the correct rating for the branch circuit fuse or circuit breaker rating?

A. Chapter Tables
B. Table 430.52
C. Article 350
D. Article 240.61

5. Select the best answer.

What is the purpose of overload protection?

A. to determine wire size and ampacity
B. to determine wire size and ampacity
C. provides strain relief for multi-conductor pushbutton stations
D. protect motors from the heat associated with an overload condition

6. True or False
Single motors are considered adequately protected if the installed branch-circuit overcurrent device meets the rating requirements of Article 610.42.

A. True
B. False

7. True or False
Hoists and their trolleys that are not used as part of an overhead traveling crane do not require overload protection for any motors under ten horse power.

A. True
B. False

8. Select the best answer.
What is the ampacity of a conductor in percent of full-load for a wound-rotor secondary heavy intermittent duty motor resistor (separate from controller)?

A. 35
B. 55
C. 85
D. 110

9. Select the best answer.
Although NEC Section 470.4 requires that conductors used for connections to resistors be rated for at least 194 degrees Fahrenheit, Navy Crane Center requires that those conductors be rated for __________ to ensure their longevity.

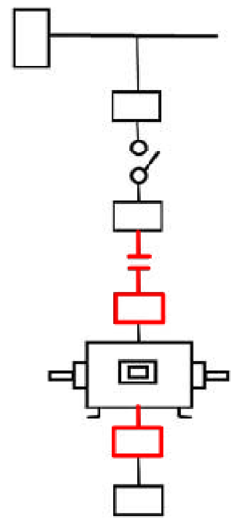
A. 257^{o}F
B. 90^{o}C
C. 212^{o}F
D. -40^{o}F

NEC 3: ARTICLES 610.51 – 610.61 AND CHAPTER 9 TABLE 4

LEARNING OBJECTIVES

In this module, you will be introduced to various aspects of the NEC beginning with section 610.51 and ending with section 610.61. You will learn requirements for motor controllers, over current protection, and upper limit switches. You will learn where to find the information that describes the minimum work area clearances for live parts and grounding requirements for cranes and hoists. Finally, you will be briefed on conduit fill and which code sections apply to this subject.

ARTICLE 610.51 MOTOR CONTROLLERS



Each motor shall be provided with an individual controller unless otherwise permitted in 610.51 (A) or (B).

(A) - Where two or more motors drive a single hoist, carriage, truck, or bridge, they shall be permitted to be controlled by a single controller.

(B) - One controller shall be permitted to be switched between motors, under the following conditions:

(1) - The controller has a horsepower rating that is not lower than the horsepower rating of the largest motor.

(2) - Only one motor is operated at one time.

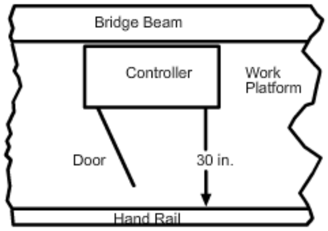
ARTICLE 610.53 CONDUCTOR OVER-CURRENT PROTECTION

Conductors of control circuits shall be protected against over current. Control circuits shall be considered as protected by over current devices that are rated or set at not more than 300 percent of the ampacity of the control conductors.
Exceptions include:

Taps to control transformers as long as the secondary circuit is protected by a device not rated or set at not more than 200 percent of the rated secondary current of the transformer and not more than 200 percent of the ampacity of the control circuit conductors.

Where the opening of the control circuit would create a hazard, as for example, the control circuit of a hot metal crane, the control circuit conductors shall be considered as being properly protected by the branch-circuit overcurrent devices.

ARTICLE 610.57 CLEARANCE



Article 610.57 defines working area clearances around live parts. The dimension of the working space in the direction of access to live parts that are likely to require examination, adjustment, servicing, or maintenance while energized shall be a minimum of two and a half feet (750 mm). Where controls are enclosed in cabinets, the door(s) shall either open at least 90 degrees or be removable.

ARTICLE 610.61 GROUNDING

Article 610.61 addresses grounding on cranes. All exposed non-current-carrying metal parts of cranes, monorail hoists, hoists, and accessories, including pendant controls, shall be bonded either by mechanical connections or bonding jumpers, where applicable, so that the entire crane or hoist is a ground-fault current path as required or permitted by Article 250, parts V and VII.

Moving parts, other than removable accessories or attachments that have metal-to-metal bearing surfaces shall be considered to be electrically bonded to each other through the bearing surfaces for grounding purposes. The trolley frame and bridge frame shall not be considered as electrically grounded through the bridge and trolley wheels and its respective tracks. In this case, a separate bonding conductor shall be provided.

Note: Navy Crane Center requires for newly procured cranes that a separate grounding wire, sized in accordance with NEC 250.122, shall be routed with all ungrounded conductors.

Table 4, Tubing & Conduit

Adding circuits and installing new equipment or appliances constitutes an alteration to a crane.

All alterations must be calculated and approved by engineering. Authorizing paperwork and other documentation will be required.

Calculating conduit fill and wire sizing for circuits to be installed on cranes is an engineering function and not a crane electrician function.

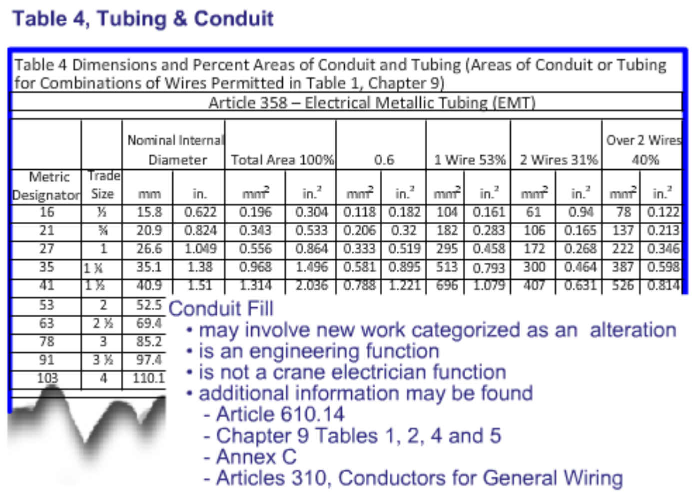


Table 4 Dimensions and Percent Areas of Conduit and Tubing (Areas of Conduit or Tubing for Combinations of Wires Permitted in Table 1, Chapter 9)

Article 358 – Electrical Metallic Tubing (EMT)

		Nominal Internal Diameter		Total Area 100%		0.6		1 Wire 53%		2 Wires 31%		Over 2 Wires 40%	
Metric Designator	Trade Size	mm	in.	mm²	in.²	mm²	in.²	mm²	in.²	mm²	in.²	mm²	in.²
16	½	15.8	0.622	0.196	0.304	0.118	0.182	104	0.161	61	0.94	78	0.122
21	¾	20.9	0.824	0.343	0.533	0.206	0.32	182	0.283	106	0.165	137	0.213
27	1	26.6	1.049	0.556	0.864	0.333	0.519	295	0.458	172	0.268	222	0.346
35	1 ¼	35.1	1.38	0.968	1.496	0.581	0.895	513	0.793	300	0.464	387	0.598
41	1 ½	40.9	1.51	1.314	2.036	0.788	1.221	696	1.079	407	0.631	526	0.814
53	2	52.5											
63	2 ½	69.4											
78	3	85.2											
91	3 ½	97.4											
103	4	110.1											

NEC chapter 9 tables and Annex C provide the information necessary to make these calculations.

Should you desire to know more about this subject, refer to:

- Article 610.14
- Chapter 9 Tables 1, 2, 4 and 5
- Annex C
- Article 310, Conductors for General Wiring, also provides information on this subject

Summary and Review

This module presented NEC Articles 610.51 through 610.61. You were introduced to requirements for motor controllers and over current protection. You know where to find upper limit switch requirements and where to find the information that describes what the minimum work area clearances are for live parts. You also learned grounding requirements for cranes and hoists. You were briefed on the locations for conduit fill and implications of adding circuits to cranes.

NOTES

NEC Module 3 Knowledge Check

Online questions may appear in a different order that those shown below.

1. True or False

Conductors of control circuits shall be protected against overcurrent.

A. True
B. False

2. Select all that apply.

Select the item(s) from the below list that describe proper clearance dimensions of the working space in the direction of access to live parts requiring examination, adjustment, servicing or maintenance while energized where controls are enclosed in cabinets.

A. two feet minimum
B. 30-inches minimum
C. spring loaded doors that automatically close
D. doors open at least 90 degrees
E. removable doors

3. True or False

All newly procured or overhauled cranes require a separate grounding wire, sized in accordance with NEC 250.122, to be routed with all ungrounded conductors.

A. True
B. False

4. Select the best answer.

Adding circuits and installing new equipment or appliances constitutes a(n) _____ to a crane.

A. alteration
B. refinement
C. improvement
D. enhancement

5. Select the best answer.

Calculating conduit fill and wire sizing for circuits to be installed on cranes is a(n) __________ function and not a(n) __________ function.

A. engineering, crane electrician
B. supervisor, mechanic
C. planner, contractor
D. crane electrician, engineering

ELECTRICAL TEST INSTRUMENTS

Learning Objectives

In this module, we will explore several electrical properties including voltage, current, resistance, frequency, and phase rotation. During this discussion, we will describe different types of electrical test instruments that are used to measure these properties, such as, voltmeters, ammeters, ohmmeters, frequency meters, and phase rotation meters. We will cover safety precautions that should be followed, not only to ensure the safe operation of the tool, but to ensure your safety and the safety of those around you as well.

Electrical Properties

While electricity can be seen and felt, usually it's only the effects that are noticed. You flip a switch and a light comes on, you push a button and a motor starts. However, the electrical properties that allow the lights to come on and the motors to run are not readily observable without the use of some sort of instrument. With the proper use of electrical test instruments, you can measure and evaluate electrical properties and ultimately, determine how to control their effects. Instruments like ammeters, voltmeters, ohmmeters, and analyzers, can be used to measure and manipulate electrical properties such as current, voltage, resistance, frequency, and phase rotation.

Voltage/Voltmeter

Voltage

Voltage is the difference in electrical potential between two points in an electric circuit, expressed in volts. It is the electrical property that forces electrons to move. Voltages as high as 1000 volts can be found on cranes. They can be positively or negatively charged and may be associated with either direct or alternating currents. A voltmeter is the instrument used to detect and measure voltage.

Voltage

• Unit of Measurement	Volt
• Range	0 to 1000 Volts
• Voltage types	Positive (+) Negative (-) Direct Current (DC) Alternating Current (AC)
• Electrical Instrument	Voltemeter



Voltmeter Types

There are two groups of voltmeters with one of those groups having two sub-sets. There are analog meters and digital meters. In the analog group are the "left-zero" and "center-zero" types. The standard analog meter, shown on the left, has a movement that zeros at the left of the scale and sweeps to the right. This meter can only measure positive voltage. The center-zero analog meter, shown in the center, has a movement that zeros in the middle of the scale and sweeps left for negative voltages and right for positive voltages. Digital meters, like the one shown on the right, display sensed voltages numerically on a screen.

Characteristics

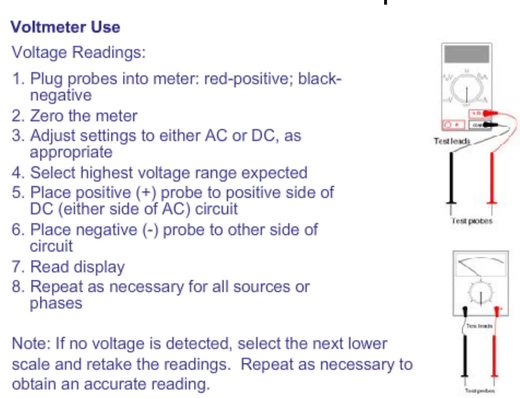
Voltmeters are designed to measure either AC or DC voltage. Some meters measure both. In the case where both AC and DC voltages are measured, voltmeters are equipped with switches to select appropriate setting and ranges. Some digital models have an "auto-ranging" feature that searches for the correct voltage range prior to displaying the sensed voltage. Analog DC voltmeters only measure DC voltage (in other words, they cannot accurately measure AC voltage) and because of this, require the correct polarity at the test leads. Digital DC voltmeters will display a positive-sign or a negative-sign with respect to which polarity is detected at the positive test lead. Analog AC voltmeters can read DC with the addition of a rectifier circuit. Care should be taken to read AC and DC voltages on the correct scales. Digital AC voltmeters will not display a voltage reading correctly unless the meter is on the appropriate setting for AC or DC.

Safety Precautions

Voltmeters are sensitive instruments and should be cared for accordingly. Do not use voltmeters to read voltages for which they are not rated. Make sure to use the correct types of test leads for the measurements being taken and make sure they are connected to the right jacks. Verify the meter functions and scales are set appropriately before taking any readings. Protect yourself, your work mates, and your gear from injury or damage from any inadvertent or unplanned contact with energized circuits. Wear approved safety equipment and observe approach distances.

Frisking (Voltage Checks)

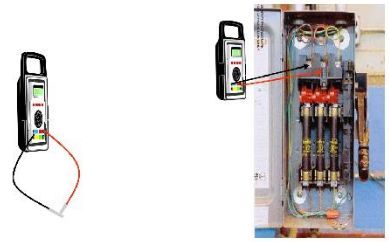
Plug the leads into the meter. Red goes to the positive (+) and black to the negative (-). Zero the meter on the ohms scale by touching the leads. Turn the selector dial or switch to the type of measurement you want. To measure direct current - a battery, for example - use direct current voltage (DCV). To measure alternating current, such as a wall outlet, use alternating current voltage (ACV). Choose the range setting. The dial may have options from 5 to 1,000 on the DCV side and 10 to 1,000 on the ACV side. Select the highest expected voltage range. If you are unsure of the voltage expected, choose the highest range. Turn the meter on. Hold the probes by the insulated handles and touch the red probe to the positive side of a DC circuit or either side of an AC circuit. Touch the other side with the black probe. Read the digital display or analog dial. Repeat as needed for all potential sources or phases involved with the work. If no voltage is detected, select the next lower scale and retake the readings. Repeat as necessary to obtain an accurate reading.



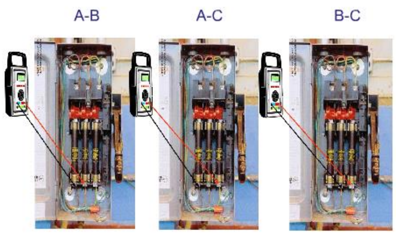
PERFORM A VOLTAGE CHECK

Voltage Check (1)

Let's perform a voltage check on a three phase disconnect box where the power has been secured for work to be performed on a load side component.



First, inspect the meter and leads for any signs of obvious damage. Plug the leads into the meter. Zero the meter on the ohms scale by touching the leads together. Next, set the meter for AC voltage and the select highest scale for the voltage expected. Check meter on a known AC source (A-B).

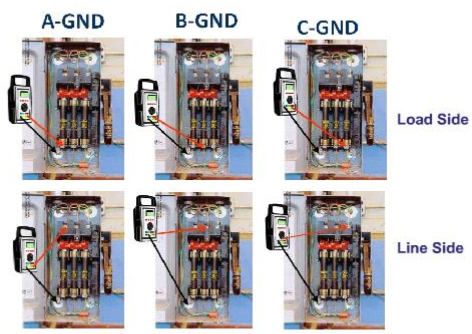


Voltage Check (2)

Check phase to phase on the load side (A-B, A-C, B-C). Terminate the check immediately if either a fixed voltage of any value or an induced voltage of 30 volts or greater is found on the load side of the disconnect switch. Notify your supervisor and engineering.

Voltage Check (3)

Check phase to ground on the load and line sides (A-GND, B-GND, C-GND). If either a fixed voltage of any value or an induced voltage of 30 volts or greater is found on the load side of the disconnect switch - terminate the check. Voltage is expected to be found on the line side of the disconnect switch. If no voltage is detected on the line side during the phase to ground checks - terminate the check. Notify your supervisor and engineering of either condition.



Voltmeter Use

Recheck the meter's voltage scale on the known AC source.

CURRENT – AMMETER (1)

Current

• Unit of Measurement	Amp
• Range	0 to 1000 amps
• Current types	Direct Current (DC) Alternating Current (AC)
• Electrical Instrument	ammeter

Current

Current is electrical property that describes the movement of electrons along a conductor. The amp is the unit of measurement for current. The range of currents encountered on cranes is from 0 to 1000 amps. The types of current are direct current (DC) and alternating current (AC). An ammeter is the electrical instrument for detecting and measuring current.

Ammeter

There are three general types of ammeters: standard analog, center-zero analog, and digital. The standard analog meter, shown on the left, has a movement that zeros at the left of the scale and sweeps to the right. This meter can only measure positive voltage. The center-zero analog meter, shown in the center, has a movement that zeros in the middle of the scale and sweeps left for negative currents and right for positive currents. Digital meters, like the one shown on the right, display sensed currents numerically on a screen. Such instruments can be equipped with a switch to select the desired range.

• Standard Analog

• Center Zero Analog

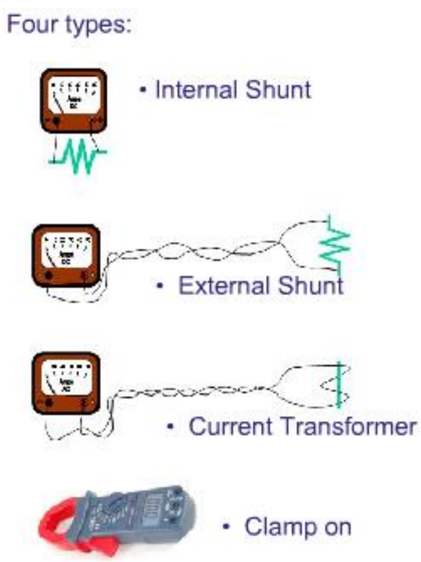
• Digital

Current Types

Ammeters can be further grouped into AC or DC current types. Ammeters are designed to measure either AC or DC current. Some meters measure both. In the case where both AC and DC currents are measured, ammeters are equipped with switches to select appropriate setting and ranges. Some digital models have an "auto-ranging" feature that searches for the correct current range prior to displaying the sensed current. Analog DC ammeters only measure DC current (in other words, they cannot accurately measure AC current) and because of this, require the correct polarity at the test leads. Digital DC ammeters will display a positive-sign or a negative-sign with respect to current flow. Analog shunt ammeters can read AC with the addition of a rectifier circuit. Care should be taken to read AC and DC current on the correct scales. Digital AC ammeters will not display a current reading correctly unless the meter is on the appropriate setting for AC or DC. Current transformers, a type of AC ammeters, must be rated for the current and frequency of the circuit being tested.

Configuration

Ammeters can also be grouped by configuration which includes internal shunt, external shunt, current transformer, and clamp-on. The internal shunt ammeter directs the majority of the current flow through a low resistance shunt, with a fraction of the current flowing to the meter movement, which is connected in parallel with the shunt.



An external shunt ammeter is used for currents greater than 10 amps. These shunts are of standard sizes and are rated for remote meter movement of 50 milliamps and 100 milliamps for full scale indication. The shunts are also rated for maximum current in sizes such as 50, 100, 200, 500, 1000, and 1600 amps.

External shunts are connected to the display instrument using twisted pair leads, and shielded cable when necessary, to prevent the meter's low voltage circuit from being affected by adjacent circuits.

Current transformers are rated for a maximum current at a rated output resistance.

Clamp-on ammeters are a very common and convenient instrument and will be discussed further on the following screen.

CURRENT – AMMETER (2)

Clamp-on

The clamp-on ammeter's characteristics make it one of the easiest and safest ammeters to use. It is designed to detect current inside an insulated conductor.

Therein lies its best advantage - the electrician does not have to test an exposed conductor.

Another advantage of the clamp-on ammeter is that the circuit does not have to be disconnected because the jaws of the clamp-on ammeter open to fit around the conductors.

Not only does this save time and effort on the part of the electrician, but the end user of the electrical service will not have to be inconvenienced by a loss of power. The design of this tool allows the electrician to move quickly and easily from one conductor to the next. Many clamp-on ammeters can read both AC and DC currents.

Precautions

Ammeters are sensitive instruments and should be cared for accordingly. Do not use any ammeter in a manner other than that for which it is designed or rated. Ammeters must always be connected in series with the circuit under test.

Always start with the highest range of an ammeter.

De-energize and discharge the circuit completely before you connect or disconnect the ammeter.

In DC ammeters, observe the proper circuit polarity to prevent the meter from being damaged.

Never use a DC ammeter to measure AC.

Make sure to use the correct types of test leads for the measurements being taken and make sure they are connected to the right jacks.

Verify the meter functions and scales are set appropriately before taking any readings.

To protect current transformers, make sure their meter circuits are shorted when not in use.

Make sure the leads are properly insulated against arcing from the high voltages produced.

Internal shunts, being low current, must not be exposed to an overcurrent. External shunt leads carry line voltage to ground and should be checked for adequate and safe insulation. Protect yourself, your work mates, and your gear from injury or damage from any inadvertent or unplanned contact with energized circuits. Wear approved safety equipment and observe approach distances.

Applications

The currents involved and the configuration of the equipment dictate the proper ammeter to use.

For continuous or remote current measurements, the shunt ammeter is best for DC and the current transformer is best for AC.

For trouble shooting and temporary measurements, the clamp-on is the best choice.

Use

Let's discuss the general procedures for using an ammeter.

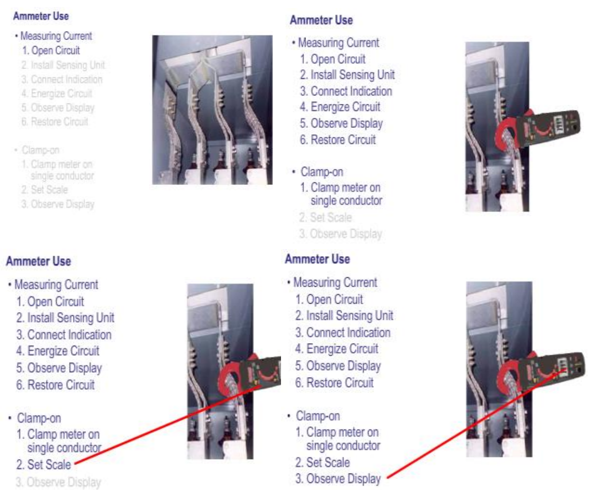
First, select the best type and configuration of ammeter for the job, as discussed previously. Open the circuit to be measured.

If using an external shunt or current transformer type ammeter, connect the sensing unit to the circuit and install the meter movement. If using an internal shunt ammeter, connect it in series with the circuit.

Energize the circuit. Operate the component being tested, as required. Observe display and record readings.

When complete, de-energize the circuit and remove the ammeter.

For a clamp-on type ammeter: First, gain access to the conductor to be tested.



Turn the meter on, if a digital type ammeter, and set the range of the meter. Most meters may have multiple range settings.

Open the clamp by depressing the thumb trigger on the side of the ammeter. Place the "jaws" around the wire and close the clamp. The clamp must be fully closed and properly seated, in order to receive an accurate reading from the conductor.

Allow a few seconds for the meter to register the amperage reading on the display.

Remove the clamp-on meter from the circuit when finished and shut the meter off so as not to wear down the battery.

Some meters may have an automatic shutoff to conserve battery power.

RESISTANCE / OHMS

Resistance

Unit of Measurement	Ohm (Ω)
• Range	milli-ohms (0.001 ohms) 10 to 1,000,000 ohms Mega-ohms (1,000,000 ohms)
• Electrical Instrument	Ohmmeter

Resistance

Resistance is the electrical property that opposes the flow of electrons. The ohm is the unit of measurement. Electrical resistance found on cranes can range anywhere from milli-ohms to mega-ohms. To help put this in perspective, a milli-ohm is .001 ohms and a mega-ohm is one million ohms. An ohmmeter is the electrical instrument for detecting and measuring resistance.

Ohmmeter

Ohmmeters can be grouped by range. Ohmmeter measurement ranges can extend from milli-ohms to megohms (or mega-ohms), and anything in-between. Numerically, that's one thousandths of an ohm to one million ohms. Some meggers (or mega-ohmmeters) can measure up to one thousand million ohms.

Safety Precautions

Before connecting an ohmmeter to a circuit, make certain the circuit is de-energized and discharged.

Do not apply power to a circuit while measuring resistance.

When you are finished using an ohmmeter, switch it to the OFF position, if an on/off switch is provided, and remove the leads from the meter.

Always adjust the ohmmeter for zero (or infinite in shunt ohmmeters) after you change ranges and before making another resistance measurement.

Using ohmmeters involves exposure to varying levels of voltage. Meggers in particular, involve high voltages. Exercise caution when using these instruments.

Follow local electrical safety policies and procedures. Wear appropriate electrical safety gear.

Ohmmeter Use

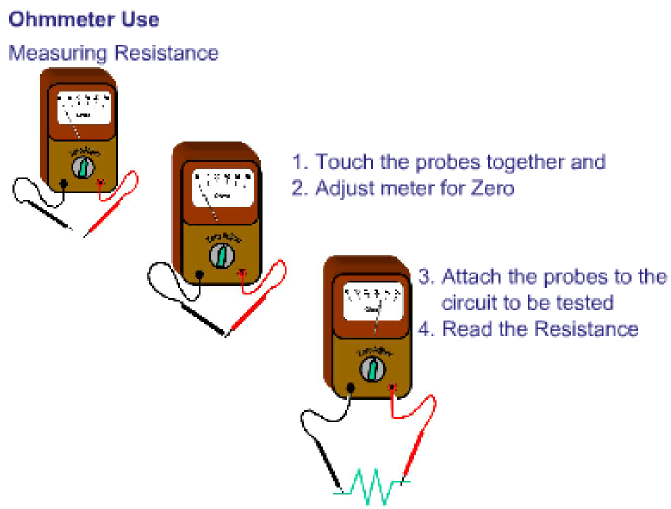
Using an ohmmeter can be as simple as - shorting the leads, zeroing the scale, connecting the leads to the circuit, and reading the display. However, we're going to explain it a little more in depth. But before we discuss how to use an ohmmeter, remember that resistance has no polarity so it doesn't matter where the leads are placed. Circuits with semiconductors or solid state devices will read differently when the leads are reversed. Circuits with capacitance will affect ohmmeter readings. Steps for using an ohmmeter safely are:

1. Select an ohmmeter suitable for the task. Analog ohmmeters are very basic and usually range from 0-10 or 0-10,000 ohms. Digital devices may have similar ranges or have an "auto-range" feature allowing the meter to read the resistance of the circuit and then selecting the correct range automatically.

2. Check the ohmmeter to see if it has a battery.

3. Plug your test leads into the sockets on your meter. For multi-functional meters, you will see a "common", or negative plug, and a "positive" plug. These may also be colored red and black.

4. Zero your meter if it is equipped with a zeroing dial. Notice that the scale reads in the reverse direction of most conventional measuring scales, that is, less resistance is to the right, and more resistance is to the left. Zero resistance should be observed when your probes are connected directly to each other, and you can adjust this by holding them together and turning the "adjust" dial until the needle on the scales is at zero ohms.



5. Touch one probe to one end of a circuit, the other to the other end, and note the reading on the instrument. If you have a 1000 ohm resistor, you can place a probe on each conductor on the resistor, and select the 1000 or 10,000 ohm range, then read the meter to see if indeed it reads 1,000 ohms.

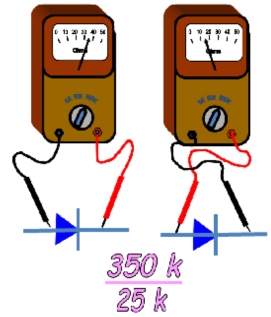
6. Isolate components in a hard wired electrical circuit to test them individually. If you are reading the ohms on a resistor in a printed circuit board, you will have to unsolder or unpin the resistor to assure you are not getting a false reading through another path in the circuit.

7. Read the resistance of a run of wire or a branch of a circuit to see if there is a short or open break in the circuit. If you read "infinite ohms", there is no path for the electrical current to follow, and in simple terms, this suggests a burned out component somewhere in the circuit, or a broken conductor. Because many circuits contain "gate" devices (transistors or semiconductors), diodes, and capacitors, however, you may not read continuity even when the complete circuit is intact, which makes it difficult to test complete circuits with only an ohmmeter.

8. Turn the ohmmeter off when not in use. Occasionally the test leads will become shorted while the device is stored, draining the battery.

Checking a Diode

Here is an example for checking a diode with an ohmmeter. Touch the positive lead to one end of the diode and the negative lead to the other end (or body, depending on construction) of the diode. With the range set for 10 thousand ohms to one million ohms, note that the display indicates 350 thousand ohms of resistance in the diode. Reverse the lead positions on the diode and adjust the range as needed. This reading is twenty-five thousand ohms. Some quick math (25 into 350) gives us a 14 to 1 ratio. A ratio of 10 to 1 or greater between readings indicates a good diode.



MULTIMETER

A multimeter is the most common electrical test device used in the field because of its versatility and portability. Multimeter, as the name implies, combines several functions into one device. It can measure current, voltage, and resistance. There are two basic types of multimeters: analog and digital. Multimeters are often small and are easily stowed in tool boxes and bags. The ohmmeter section of the device is not used on live circuits. The current section of this device must not be used to read voltage. Be careful to always select the correct function based on the electrical property to be measured. Failure to observe this precaution may result in damage to the meter. The meter must always be turned off or turned to the volt scale (as applicable) when not in use, since the ohmmeter portion is powered by batteries which will run down if left on.

FREQUENCY METERS

Frequency Meters

Frequency is the electrical parameter that describes the number of cycles a wave form repeats per unit time. A frequency meter is a device for measuring the repetitions per unit of time (customarily, a second) of a complete electromagnetic waveform. To maintain and troubleshoot some types of electronic circuits on cranes, frequency measurements are required. Frequency meters can be simple or complex, analog or digital, panel mounted or hand held, and permanently installed or portable.

Safety Precautions

The precautions taken depend on the frequency meter used. The sensing probe is usually resistant to over voltage. The reference lead can be connected to any conductor without harm. To provide personal protection, the probes for frequency meters are designed and well suited for sensing high voltage while protecting the operator. Care must always be exercised when working near energized conductors.

Use

To measure the frequency on a circuit:

1. Connect the reference lead to system ground or one of the line leads.
2. Connect the sensing probe to the circuit to be tested.
3. Adjust the frequency meter sensitivity for the lowest setting that produces a stable reading.
4. Adjust the meter period for a reading that utilizes most of the meter's display.
5. Take the reading.

PHASE ROTATION

Phase Rotation

Unit of Measure	Standard / Reversed Rotation
Range	110 to 220 VAC & 110 to 440 VAC
	60Hz-400 Hz
Instrument	Phase Rotation Meter

Phase Rotation

Three phase power is used on many crane circuits. To operate correctly, most of these circuits must be supplied with power having phases that rotate correctly. Phase rotation is the electrical property that describes the order in which the conductors of a multi-phase system cycle. The correct instrument for evaluating phase rotation is the phase rotation meter.

Safety Precautions

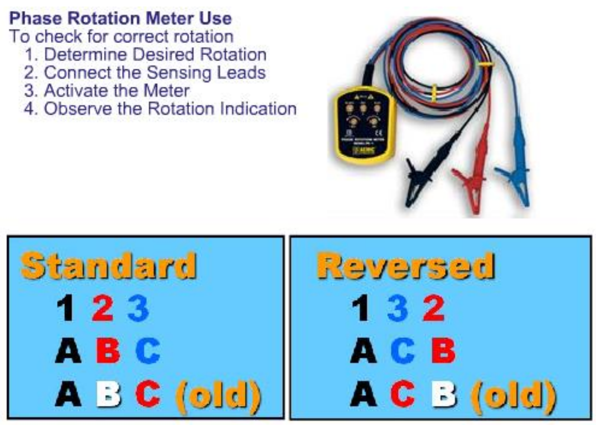
Phase rotation meter choice dictates precautions followed. Read and follow OEM instructions and safety notes. Phase rotation meters are rated for specific voltage and frequency ranges; therefore, they should not be used on circuits where the voltage or frequency may exceed that for which the meter is rated. The sensing leads on many phase rotation meters are designed to protect the user. None the less, when working in, on, or around energized circuits, always follow local electrical safety policies and procedures and wear appropriate electrical safety gear.

Meter Types

Phase rotation meters are of two basic types, induction and digital. They consist of the instrument and three leads.

Meter Use

To check for proper rotation, you must first determine the desired rotation. The proper, or desired, rotation is dependent upon the components attached to the circuit. Phase designations, as shown, are either standard or reversed. After determining the desired rotation, connect the sensing leads in accordance with the phase designations. Activate the meter. Observe indicate phase rotation and compare to desired rotation. Report results to supervisor and engineering and/or make authorized adjustments.



Review and Summary

In this module, we explored several electrical properties including voltage, current, resistance, frequency, and phase rotation. During this discussion, we described different types of electrical test instruments that are used to measure these properties, such as, voltmeters, ammeters, ohmmeters, frequency meters, and phase rotation meters. We also covered many safety precautions that should be followed, not only to ensure the safe operation of the tool, but to ensure your safety and the safety of those around you as well.

NOTES

Electrical Test Instruments Knowledge Check

Online questions may appear in a different order that those shown below.

1. Select the best answer.

Name 4 electrical properties that crane electrical maintenance workers monitor.

A. voltage, frequency, amperage, and horsepower
B. current, horsepower, kilowatts, and voltage
C. voltage, current, resistance, and phase rotation
D. watts, electromotive force, current, and resistance

2. Select the best answer.

An ohmmeter is used to measure _____, and voltmeter is used to measure _____, and an ammeter is used to measure _____.

A. phase rotation, current, voltage
B. current, voltage, resistance
C. resistance, voltage, current
D. voltage, current, resistance

3. Select all that apply.

Identify the instrument used to measure and evaluate electrical properties.

A. ammeter
B. voltmeter
C. pm-meter
D. ohmmeter

4. Select all that apply.

When using a multimeter…

A. Plug probes into the appropriate jacks: red (+), black (-).
B. If measuring voltage, put the meter on the appropriate voltage setting :(AC) or (DC).
C. If checking voltage, set meter to the lowest setting possible.
D. Ensure the meter has no physical damage.
E. Ensure meter is reading correctly by checking on a known source (AC or DC) before and after each use.
F. All answers are correct.

5. True or False

You are verifying phase to ground on the load side of the disconnect switch. If either a fixed voltage of any value or an induced voltage of 30 volts or greater is found on the load side of the disconnect switch – restart the frisk.

A. True
B. False

6. Select all that apply.
When frisking an AC disconnect switch you should…

A. Check meter on a known AC source before and after frisking.
B. Check phase to phase on both the line side and load side.
C. Check phase to ground on both the line side and load side.
D. Check meter for expiration date.

7. True or False
Voltage is expected on the line side of a disconnect switch. If no voltage is detected on the line side during the phase to ground checks, you should terminate the verification checks.

A. True
B. False

8. Select the best answer.
What is the unit of measurement for resistance?

A. voltage
B. resistance
C. ohm
D. current

9. Select the best answer.
When measuring resistance with a meter you should…

A. touch the probes together and adjust meter for zero.
B. attach the probes to the circuit to be tested.
C. read for resistance.
D. all the above

10. Select the best answer.
While checking a diode, what is the proper ratio that indicates a food diode?

A. less than 10:1
B. 5:1 or greater
C. less than 50
D. 10:1 or greater

FASTENERS

LEARNING OBJECTIVES

This module presents an overview of fasteners. You will…

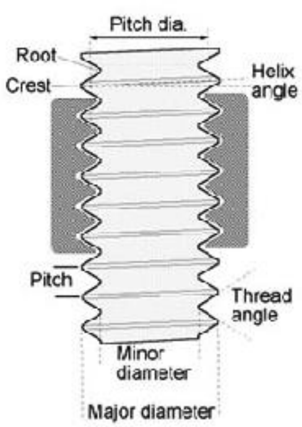
- know how to identify various types and grades of fasteners including nuts, bolts, screws, washers, pins and retainer rings
- see how to identify potentially counterfeit fasteners
- learn how a bolted joint works and the relationship between clamping force, torque and tension

Based on this understanding and other guidelines provided in this module you will…

- know how to select and use the proper torque tool to tension fasteners utilizing the proper installation techniques discussed
- will know where to find alternate torque values to use for electrical connectors when none are provided

THREAD TERMINOLOGY

A thread is a continuous helical ridge formed on the outside of a bolt (or on the inside in the case of a nut) and set at an angle to the axis of the bolt or nut. The top, or peak, of



the helical ridge is called the crest. Between each crest is a space called the root. The major diameter is measured from the crest on one side of the bolt to the crest on the opposite side. The thread forms a "V" shape between crests. The angle of this "V" is called the thread angle, and is determined by fastener engineers. The distance from the root on one side of the bolt to the root on the opposite side is called the minor diameter. Thread pitch is the distance from one crest to the adjacent crest. Thread pitch is best measured using a thread pitch gauge, as shown on the right. Another critical aspect of thread fit and interchangeability is call "pitch diameter". The pitch diameter is measured at a point where the thickness of the thread equals the distance across the groove (approximately half way between the major and minor diameters). The “flank” (not labeled) is the angled side of the thread. The “point” (not labeled) is the chamfer on the threaded end of the bolt, which permits easier starting of the thread.

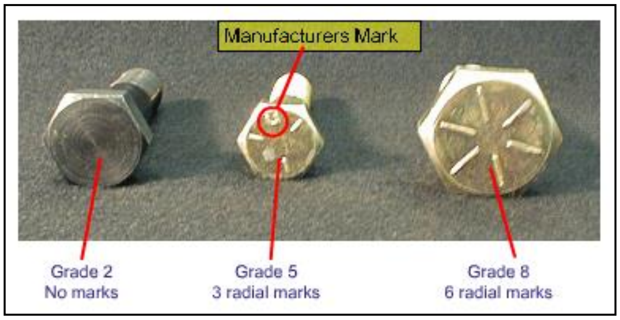
BOLT IDENTIFICATION

Bolt Identification

Bolts can be identified by several different head configurations. Carriage bolts are designed for the square portion of the shank to hold the bolt from turning by either fitting into a square hole or biting into soft material. Jacking bolts are commonly used to precisely move motors, brakes, and gear reduction units on their foundations. They may also be found on some brush rigging assemblies. Hex head bolts are the most common type of bolt. The head has six sides to fit standard 6 and 12 point sockets and wrenches. Allen head or socket head bolts have an internal hex designed to fit an Allen wrench or hex socket. Finally, square head bolts are not common in crane applications. They can be used as jacking bolts when the square head is about the size of the shank.

Identifying Bolt Grades

In addition to identifying cap screws by shape, the markings on the heads offer further identifiable features such as grade and mechanical properties. Professional organizations such as the American Society for Testing and Materials (ASTM), the Society of Automotive Engineers (SAE), and the International Standards Organization (ISO) have established grade markings for fasteners to identify their various mechanical properties. Grade markings for bolts, as well as nuts, are too numerous to list here. Plus, older markings still exist and new markings have been introduced. Fastener markings can be researched on the internet through various fastener sites and ASTM, SAE and ISO sources. Some of the more common SAE markings are shown.



The bolts in these classification groups are readily identifiable by the markings, or lack of, markings, on the bolt heads. Markings will not only tell you the grade of the bolt, but also the manufacturer. Grade 1 or 2 bolts have no markings. Grade 5 bolts have 3 radial marks and grade 8 bolts have 6 radial marks. Every legitimate manufacturer of bolts in the United States of America has an individual letter or mark, which identifies their products.

Notice that the grade 8 cap screw in this picture does not have a manufacturer's mark. The absence of a manufacturer's mark should be suspect and initiate reporting and evaluation procedures to ensure fasteners with adequate mechanical properties are being installed on weight handling equipment.

Identification Grade Mark	Specification	Material	Mechanicl Properties: Proof Load (psi)	Yield Strength Min. (psi)	Tensile Strength Min. (psi)
No Grade Mark	SAE J429 Grade 1	Low or Medium Carbon Steel	33,000	36,000	60,000
	ASTM A307 Grades A&B	Low Carbon Steel	-	-	
	SAE J429 Grade 2	Low or Medium Carbon Steel	55,000 33,000	57,000 36,000	74,000 60,000
	SAE J429 Grade 5	Medium Carbon Steel, Quenched and Tempered	85,000 74,000	92,000 81,000	120,000 105,000
	ASTM A449		85,000 74,000 55,000	92,000 81,000 58,000	120,000 105,000 90,000
	SAE J429 Grade 8	Medium Carbon Alloy Steel, Quenched and Tempered	120,000	130,000	150,000
	ASTM A354 Grade BD	Alloy Steel, Quenched and Tempered			

Note: Bolts are required to have both Grade Markings and Manufacturer Markings. Mechanical bolts follow the SAE J429 standards and Structural bolts follow the ASTM F3125 standards.

Grade Markings

Here is a chart with the standard SAE bolt head markings. These are the recognized grade markings for SAE standard grades. Most manufacturers use at least grade 5 bolts in their machinery. Some engine manufacturers use all grade 8 fasteners.

Metric Bolts

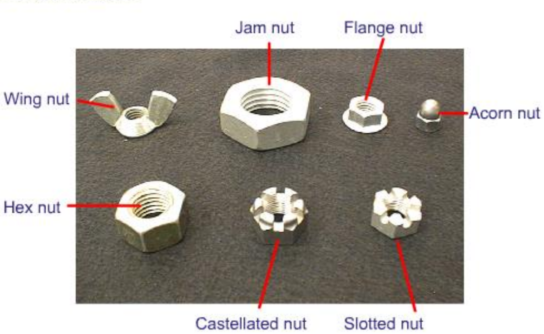
Since many components in cranes are manufactured internationally, you should be able to identify metric fasteners. The main concern, of course, is proper bolt selection and installation. A related concern would be accidentally installing a metric bolt into a hole or nut with non-metric threads or vice versa. If mixed up, thread damage may result which is costly to repair and if left unnoticed, fastener failure will likely result.

Nut Identification

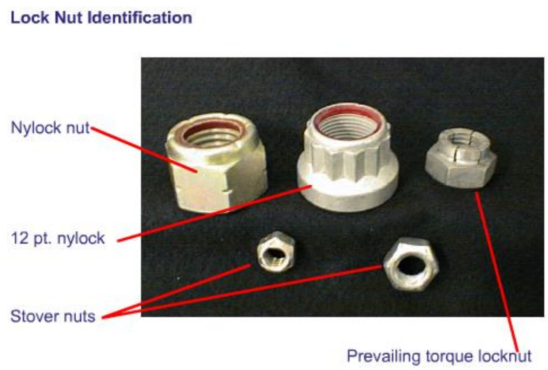
Nut Identification

Nuts can be identified by their shape and grade. Nuts are used in conjunction with screws to create a bolted joint. The most common type of nut is the hex nut, which comes in various sizes and grades to match the screw to which it will be fastened. Other types of nuts include wing nuts, jam nuts, flange nuts, acorn nuts, castellated nuts and slotted nuts. Wing nuts have ears built into the sides of the nut which are used for installation and removal by hand; they should only be used in applications where quick access or repetitive removal is the prime consideration. Jam nuts are shaped like hex nuts but are about half the thickness of a standard hex nut. Jam nuts are used like lock nuts to prevent other threaded pieces from loosening. Flange nuts have a shoulder-like area resembling a washer or "flange". They are used on devices that required periodic adjustments. Acorn nuts, or cap nuts, have rounded, closed heads to protect threads. Castellated and slotted nuts are designed to be locked in position by use of a cotter pin. Castellated nuts have slots cut through a raised portion of the nut while slotted nuts have the recesses cut into the hex portion of the nut.

Nut Identification



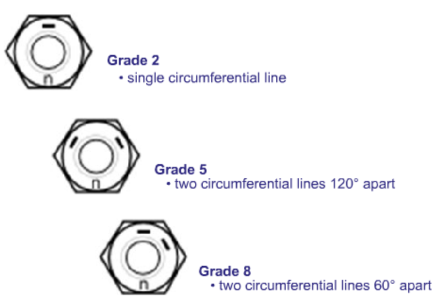
Lock Nut Identification



Shown here are different types of lock nuts. Lock nuts are manufactured with a feature the helps to keep their partner bolt from unscrewing and loosening. Some common types of locknuts include prevailing torque locknuts and nylon insert locknuts, often called Nylock nuts. Nylock nuts have a piece of plastic, or nylon, installed inside the nut. As the bolt is threaded through the nut, it cuts new threads into the nylon. The nylon responds by compressing around the threads of the bolt. This creates a "locking" action which assists in preventing the bolt from loosening. It should be noted that repeated use of a Nylock nut reduces the nylon's ability to compress. A rule-of-thumb for determining if a Nylock nut can be re-used is - if a bolt can be threaded completely through the nut by hand, it should not be re-used. Prevailing torque nuts have a feature, like the Nylock nut, that compresses around the threads of the bolt. Only in this case it's metal. Some prevailing torque nuts have slotted upper sections which are bent inwards, some have tapers, and others are manufactured out-of-round or with distorted threads. Care must be exercised when using or re-using locknuts. Review local policies regarding the use of locknuts. Many locknuts should not be used more than once.

Nut Grade Markings

Nuts, like cap screws, have grade markings to identify their properties. Nuts shall match the grade of its partner cap screw. The consequences of mismatching nut and bolt grades can be catastrophic. For example, installing a grade 2 nut on a grade 8 cap screw in a high tensile application may cause the cap screw to strip the threads of the nut when exposed to the stresses of the application. Grade markings for nuts, as well as bolts, are too numerous to list here. Plus, older markings still exist and new markings have been introduced. Fastener markings can be researched on the internet through various fastener sites and ASTM, SAE and ISO sources. Some of the more common grades and markings include SAE grade 2 with a single circumferential line; SAE grade 5 with two circumferential lines 120° apart; and SAE grade 8 with two circumferential lines 60° apart. Don't assume that nylon locking nuts are grade 8 because of the 6 crimp marks by the insert. Nylon locking nuts will have notches cut in the hex for grade 5 or 8.



FASTENERS

This accident occurred, in part, due to fastener failure; the wrong fastener type was installed. As seen here, catastrophic failure can result from improper fastener selection and installation. In this case, a lower grade bolt was installed in a location where a higher grade bolt was required. The operational stresses were too great for the bolt, which failed. This in turn placed additional stress on the remaining bolts, which failed. The result, as seen here, allowed the boom to free-fall to the ground.

WASHER IDENTIFICATION

Lock Washer Identification

A lockwasher is a solid or split washer that is placed underneath a nut or cap screw to help prevent loosening. The helical spring washers, commonly called split washers, are manufactured from spring steel. They have a split in the washer body with the ends tapering up, like a coil or spring. When the washer is compressed between the nut and the work piece, it provides a minimal amount of spring tension on the clamped joint. This constant spring tension is what aids in maintaining tightness. Depending on the properties of the work piece and the nut, split washers may also bite into the surrounding metal, providing additional resistance through friction. The high collar helical spring washer is used in places where a tight fit exists around the shank of the bolt. The outside diameter is smaller than the regular split washer of the same nominal size. External and internal tooth lockwashers, or star washers as they are commonly called, utilize teeth that are located on the outside or inside of a ring. This design increases the coefficient of friction between the nut and the work piece and aids in maintaining tightness. External star washers, with their teeth on the outside of the ring provide a better connection with large fastener heads. Internal star washers, with their teeth on the inside of the ring ensure a good connection with smaller fastener heads. Lockwashers are not used on structural connections and connections where bolts are torqued. All lockwashers are sized by the nominal dimension of their internal diameter.

Flat Washer Identification

Flat washers are identified by their size and type. Flat washers are sized by their ID, which will correspond nominally with the bolt size they are meant to fit. In general, washer design allows about one thirty-second of an inch clearance between the ID of the washer and the OD of the bolt. Washers are designed to spread the load of the bolt (or nut) over a larger surface, and to protect the surface from damage due to fastener tightening. The two common classifications for outside diameter are the SAE and United States Standard (USS) sizes, with USS being the larger of the two. When using flat washers, always ensure that the washers are graded for use with the fasteners, as recommended by the manufacturer.

Tab Washers

Tab washers are also used for locking purposes. They are used, for example, to lock a bearing nut into a certain position to achieve a specified pre-load on a bearing. Many tab washers have multiple tabs so that they may be reused, however, if the washer has only one set of tabs, after it has been bent over once and straightened out, it should not be reused.

Socket Head Screw

Round Head Screw

Fillister Head Screw

Countersunk Head Screw

Screw Identification

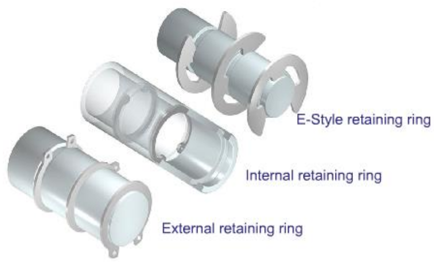
Shown here are examples of typical screws. Screws may be divided up into basic groups. Screws use standard SAE thread sizes, but their heads come in different styles for a variety of different applications. Among the styles are socket head, round head, flat head, truss head, oval head, fillister head, clutch head, pan head, and hex slot head. Tapping screws have a thread that cuts into the material being threaded (usually sheet metal) and forms its own thread as it is being turned. These may also be referred to as thread-forming or sheet metal screws. Set screws are generally used to hold a collar, pulley, or gear in place. They may have a head, but most have no head and a hexed recess for an Allen wrench. The ends of the screw may be flat, pointed, cupped, half or full dog for fitting into a drilled recess.

Pin Identification

There are several types of pins in common use for locking and positioning parts. Straight pins are usually used in conjunction with a clevis. They are normally drilled on one end for a cotter pin. Cotter pins are used to retain clevis pins, to keeps nuts from backing off and other applications where ease of disassembly is a consideration. They are sized both by their diameter and their length. Taper pins are designed to fit in a hole which has been reamed with a special tapered reamer. They can only be removed by tapping them in the opposite direction from which they were installed. Split pins, spring pins, or roll pins are made from rolled spring steel. When the pin is installed, it is compressed because the hole is smaller than the pin and this compression keeps the pin in the hole. These pins are larger than their nominal size.

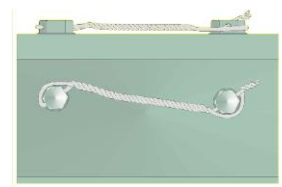
Retaining Ring Identification

Shown here are the three basic types of retaining rings, commonly referred to as snap rings. The external snap ring is applied with special pliers which expand the tapered ring over a shaft and then allow it to relax and fit into a special groove. The internal snap ring is also applied with special pliers which compress the tapered ring for placement into a bore or housing, then allow it to expand and seat into a circumferential groove. Reduced cross-section external e-rings contain three prongs connected by a reduced section to provide greater resilience during installation. They are installed radially, usually by means of an applicator, and provide a high shoulder for abutment by a retained part.



Lock Wire

Lock wire can be used to keep a fastener or series of fasteners from backing out. The wire will not necessarily keep the fastener tight, but it will keep the fastener from coming undone. There are many different ways to run lock wire. MIL-STD-763, Locking Devices, gives tips and techniques for running lock wire. The main concern when running lock wire is to ensure that the lock wire tightens as the fastener loosens. Lock wire comes in a variety of sizes and materials.



Anaerobic Thread Lockers

Anaerobic thread lockers are a very good method of preventing a threaded fastener from backing off. They must be applied with care to clean, primed threads. The solution should start about one thread back from the end of the bolt and should not be applied too heavily as hydraulic lock can take place. Different compounds and strengths are manufactured for different applications. Be sure that the one used is correct for the application and that the manufacturer's installation is followed. The compounds have a cure time that must be adhered to in order for the locking effect to take place.

COUNTERFEIT FASTENERS

Counterfeit Fasteners

Why would anyone counterfeit fasteners? For the same reason someone counterfeits $100 bills: to make money by passing them off as the real thing.

Counterfeit Fasteners Markings

The Industrial Fastener Institute has concluded that over half of all Grade 8 bolts checked in 1986 were counterfeit. Since then, heightened awareness of counterfeit foreign fasteners has alleviated the problem somewhat, but many undiscovered counterfeit fasteners are still on equipment in the field, and continue to be produced by questionable companies. The counterfeit bolt is very hard to detect. In fact, it can cost several hundreds of dollars to determine the exact metallic content of a single bolt. For this reason, few tests are done unless the bolt fails, and by then it's too late. One of the primary ways you can identify a counterfeit fastener is by the markings on the top of the bolt head. Legitimate manufacturers place a symbol or letter on the heads of the bolts they produce to identify their product. Bolts without these identifying marks should be immediately removed from service. The Department of Energy has additional information on counterfeit bolts

No manufacturer's markings on bolt heads

Counterfeit Fasteners Yielding

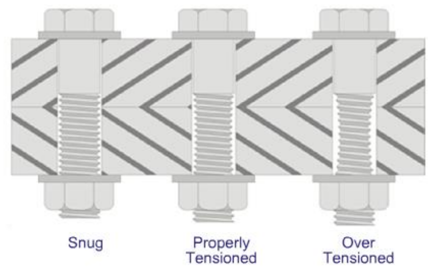
If a bolt yields before reaching the specified torque or nut position, it may be counterfeit.

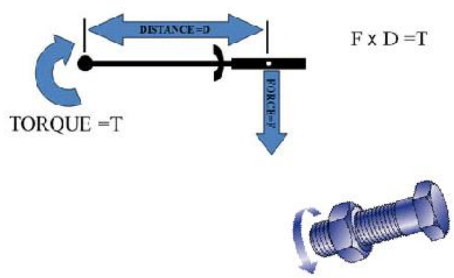
Counterfeit Fasteners Yielding

When you are tightening a bolt and the bolt yields before it reaches the specified torque or nut position, this may be an indication that the bolt is counterfeit. However, not all yielding problems are indications of counterfeit fasteners. If you use a torque value from a torque chart for non-lubricated bolts and then apply lube to the bolt being torqued, it may cause yielding. Also, using a grade 8 torque specifications for a grade 5 or less bolt, may cause a bolt to yield. If everything is proper and the bolt yields, you should investigate.

How a Fastener Works

When a fastener is properly tensioned, it stretches and applies a clamping force to the materials between its clamping surfaces. The bolt works on the same principle as a rubber band. When the rubber band is stretched over a roll of paper, the elastic force of the rubber band holds the papers together. If you use a rubber band which is too large, it exerts no clamping force and the papers will unroll. If the rubber band is too small, it will have to stretch too much and it may break or stretch to a point where it loses its elasticity and cannot return to its original shape. A bolt works in much the same fashion. When it is properly tensioned, the stretch of the bolt holds the material between it in place. If it has not stretched tightly enough, the materials may slip, and if it is tightened too much it may break or yield. Proper tensioning of a fastener is one of the most important parts of the joint assembly process.





What is Torque?

Torque is the amount of twisting force applied to a fastener. Torque is expressed as a certain amount of force (given in pounds), exerted over a certain distance (given in feet or inches). The torque is the product of these two measurements. Engineers have found, through experience and calculations, how much torque must be applied to a given fastener to stretch it the proper amount and provide the necessary tension. Be aware, however, that factors like rust, corrosion, and so forth can affect how much stretch will be realized from a given amount of torque.

Torque Screwdrivers

All torque screwdrivers include a variable torque range, and all have a unique torque limiting clutch that disengages once the preset torque has been reached. This prevents over-tightening. Torque screwdrivers measure torque ranges from 6 inch-ounces to 190 inch-pounds. Currently, no single tool measures this entire range. Torque screwdrivers also include several clutch types, including “cam-over”, “cushion clutch”, and “auto-shut off”. Most of these clutch styles can be found in electric screwdrivers, air screwdrivers, impulse screwdrivers, manual torque screwdrivers, and cordless torque screwdrivers. Each style includes the ability to preset a specific torque value.

A Cam-over clutch is usually found in a manual torque screwdriver where the clutch simply “cams-over”, meaning that it signals the maximum torque has been achieved. Cushion clutch or “slip clutch” styles are found in both electric screwdrivers and air screwdrivers. This clutch style is similar to the “cam-over” when once the final torque is reached because the clutch continues to cam over and slip. It will continue to run until the operator releases the throttle. Auto-shut off clutches are designed for fastening of critical applications. Auto shut off clutches provide precision torque control and reduce energy consumption because, once the maximum torque is reached, the tool automatically turns off.

Torque Wrenches

Wrenches: Click Type

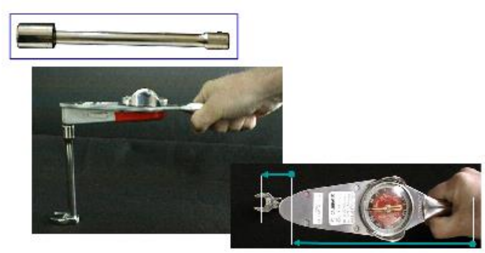
There are two types of torque wrenches in general use: the click type and the dial type. The click type must be set for the torque required and then pulled until an audible click is heard and a slight give is felt. The click type is more convenient when working in a confined space where watching the dial of a torque wrench would be hard to do. The click type should be wound down to the lowest torque setting when not in use to preserve the spring.

Dial Type

The other type of torque wrench in common use is the dial type. The dial type torque wrench allows the user to see the torque which is being applied. This allows a great deal of precision in torqueing as exactly the same torque can be applied each time. The dial type has the drawback of being hard to operate and read at the same time. This is true particularly of the larger wrenches.

Adapters and Extensions

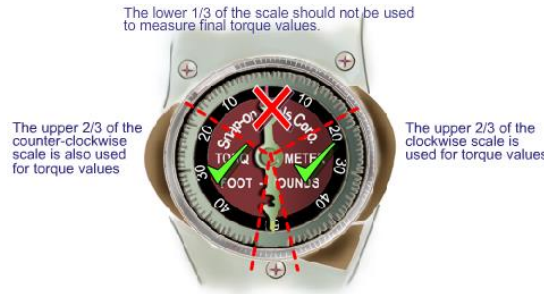
Adapters and extensions may sometimes be used in conjunction with a torque wrench.



Adapters extend lengthwise from the drive square. They change the torque value. If adapters are used, the amount of torque exerted by the wrench will not be the same as the reading on the dial. A mathematical formula must be used to determine the actual torque wrench reading. If your facility has a fixture for checking torque wrenches, the fixture is an easier way of verifying the torque with a certain adapter set-up.

Extensions extend longitudinally and attach to the drive square for the purpose increasing the height of the torque wrench. They do not change the torque value.

Selecting



Selecting the proper torque wrench is an important first step. Find a wrench where the value to be torqued is not on the lowest range of the wrench. Torque wrenches shall be selected so that the final torque value for the fastener(s) being tensioned falls within the upper two-thirds of the wrench range.

If foot pound wrenches are too big, get an inch pound wrench. For small torque values (less than 20 foot pounds) an inch pound torque wrench may be the better choice. To determine inch pounds, multiply the foot pound value by 12 inches per foot. For example: 10 foot pounds times 12 inches per foot = 120 inch pounds.

Proper Torque Values

Let's discuss some proper torqueing techniques.

First, tighten all fasteners until firm contact is made. Apply the torque tool (wrench or driver) and pull or turn smoothly and evenly. To avoid damaging the fastener and tool, do not jerk the tool during the tensioning process.

Fasteners should be tightened in at least three relatively equal increments. Follow the specified pattern for tightening a group of fasteners. If no pattern is specified, tighten from the inside out, alternating back and forth from side to side, thus allowing the piece to be tightened evenly.

Starting with the first torque value increment, tighten all fasteners, in pattern, to the same value, about 30 percent of the final torque value.

Repeat using the same pattern, but this time torque the fasteners to the second torque value increment, about 65 percent of the final torque value.

The third pass should bring all the fasteners to the final torque value specified.

Finally, make one more pass, in pattern, on all the fasteners to verify each fastener is tensioned to the final torque value.

Watch for yielding. If the torque reading stops increasing as the fastener is being tightened, the fastener may have yielded. If you suspect yielding, stop the job and seek resolution before continuing and further.

LISTED TORQUE VALUES

Listed Torque Values

Making electrical connections is the electrical task that most often requires knowledge of fasteners and torque values. Some helpful facts about electrical connection devices are that most UL approved devices for making power distribution connections have the required torque values listed on a label. The listed torque values should always be used when available. If not available, AWG, KCMIL or other recommendations should be consulted. Your engineering department can also assist in determining the proper torque values. The NEC also provides torque values for electrical connectors.

AWG or KCMIL

Shown here is the Informative Annex I, Table I.1 of the NEC book. It covers four types of electrical connection fasteners according to two wire groups. For reference to the conductor size, the American Wire Gauge (AWG) is shown under the 'Test Conductor Installed in Connector' section of the chart.

The first slotted head group has a slot width of 1.2 mm (0.047 in.) or less and slot length of 6.4 mm (1/4 in.) or less.

The next group has a slot width over 1.2 mm (0.047 in.) or slot length over 8.4 mm (1.4 in.).

The last two are split-bolt connectors and other connectors.

This table provides torque values for electrical fasteners and should be used for guidance only if no tightening information on a specific wire connector is available. The information in this table was taken from UL 486A and 486B, Wire Connectors and should not be used to replace the manufacturer's instructions, which should always be followed.

Table I.1 Tightening Torque for Screws

Test Conductor Installed in Connector		Tightening Torque, N-m (lbf-in.)							
		Slotted head No. 10 and larger*							
		Slot width 1.2 mm (0.047 in.) or less and slot length 6.4 mm (1/4 in.) or less		Slot width over 1.2 mm (0.047 in.) or slot length over 8.4 mm (1.4 in.)		Split-bolt connectors		Other connectors	
AWG or kcmil	mm^2								
30-10	0.05-5.3	2.3	(20)	4.0	(35)	9.0	(80)	8.5	(75)
8	8.4	2.8	(25)	4.5	(40)	9.0	(80)	8.5	(75)
6-4	13.2-21.2	4.0	(35)	5.1	(45)	18.5	(165)	12.4	(110)
3	26.7	4.0	(35)	5.6	(50)	31.1	(275)	16.9	(150)
2	33.6	4.5	(40)	5.6	(50)	31.1	(275)	16.9	(150)
1	42.4	—		5.6	(50)	31.1	(275)	16.9	(150)
1/0-2/0	53.5-67.4	—		5.6	(50)	43.5	(385)	20.3	(180)
3/0-4/0	85.0-107.2	—		5.6	(50)	56.5	(500)	28.2	(250)
250-350	127-177	—		5.6	(50)	73.4	(650)	36.7	(325)
400	203	—		5.6	(50)	93.2	(825)	36.7	(325)
500	253	—		5.6	(50)	93.2	(825)	42.4	(375)
600-750	304-380	—		5.6	(50)	113.0	(1000)	42.4	(375)
800-1000	405-508	—		5.6	(50)	124.3	(1100)	56.5	(500)
1250-2000	635-1010	—		5.6	(50)	124.3	(1100)	67.8	(600)

*For values of slot width or length not corresponding to those specified, select the largest torque value associated with the conductor size. Slot width is the nominal design value. Slot length shall be measured at the bottom of the slot.

Slotted Screw

Shown here is the Informative Annex I, Table I.2 of the NEC book. It addresses torques in inch-pounds for slotted head screws smaller than number 10, for use with 8 AWG and smaller conductors.

Table I.2 Tightening Torque for Slotted Head Screws Smaller Than No. 10 Intended for use with 8 AWG (8.4 mm^2) or Smaller Conductors

Slot Length of Screw*		Tightening Torque, N-m (lbf-in.)	
mm	inch	Slot width of screw smaller than 1.2 mm (0.047 in.)**	Slot width of screw 1.2 mm (0.047 in.) and larger**
Less than 4	Less than 5/32	0.79 (7)	1.0 (9)
4	5/32	0.79 (7)	1.4 (12)
4.8	7/16	0.79 (7)	1.4 (12)
5.5	7/32	0.79 (7)	1.4 (12)
6.4	1/4	1.0 (9)	1.4 (12)
7.1	9/32		1.7 (15)
Above 7.1	Above 9/32		2.3 (20)

*For slot lengths of intermediate values, select torques pertaining to next shorter slot lengths. Also, see 9.1.9.6 of UL 486A-2003, Wire Connectors and Soldering Lugs for Use with Copper Connectors, for screws with multiple tightening means. Slot length shall be measured at the bottom of the slot.
**Slot width is the nominal design value.

Recessed Allen Head or Square Drive Torque

Shown here is the Informative Annex I, Table I.3 addresses tightening torques for screws with recessed Allen or Square drives.

Table I.3 Tightening Torque for Screws with Recessed Allen or Square Drives

Socket Width Across Flats*		Tightening Torque, N-m (lbf-in.)	
mm	inch		
3.2	1/8	5.1	(45)
4	5/32	11.3	(100)
4.8	3/16	13.5	(120)
5.5	7/32	16.9	(150)
6.4	1/4	22.5	(200)
7.9	5/16	31.1	(275)
9.5	3/8	42.4	(375)
12.7	1/2	56.5	(500)
14.3	9/16	67.8	(600)

*See 9.1.9.6 of UL 486A-2003, Wire Connectors and Soldering Lugs for Use with Copper Connectors, for screws with multiple tightening means.

OXIDATION INHIBITOR

An oxidation inhibitor is often used when working with electrical connection devices. An inhibitor should be applied to all fasteners' threads and the attaching conductors if the connection device is aluminum. Most aluminum connection devices have the letters "AL" stamped on them. Also, connection surfaces of all aluminum conductors should be treated before connections are made.

REVIEW AND SUMMARY

This module presented an overview of fasteners. You know how to identify various types and grades of fasteners including nuts, bolts, screws, washers, pins and retainer rings. You can identify potential counterfeit fasteners. You understand how a bolted joint works and the relationship between clamping force, torque and tension. Based on that understanding and other guidelines provided in this module, you know how to select and use the proper torque wrench or screwdriver to tension fasteners utilizing the proper installation techniques discussed. You know where to find alternate torque values to use for electrical connectors when none are provided.

NOTES

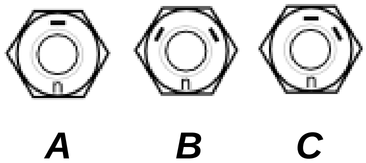
Fasteners Knowledge Check

Online questions may appear in a different order that those shown below.

1. Select the best answer.

Identify the grade eight nut marking.

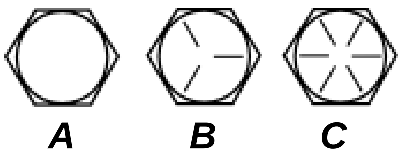
A.
B.
C.



2. Select the best answer.

Identify the grade five bolt head marking.

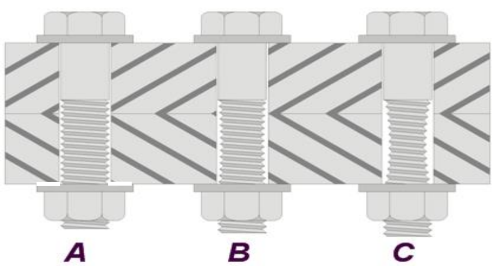
A.
B.
C.



3. Select the best answer.

In the picture below, which of these fasteners is properly tensioned?

A.
B.
C.



4. Select the best answer.

From the list below, select the item that best describes the pictured fastener.

A. English
B. metric
C. USS
D. ISO

5. Select the best answer.

What is missing in this picture?

A. manufacturer mark
B. ASTM markings
C. thread pitch mark
D. nothing is missing

6. Select the best answer.
The absence of a(n) ________ on a nut or bolt should be suspect and initiate reporting and evaluation procedures to ensure fasteners with adequate mechanical properties are being installed on weight handling equipment.

A. thread pitch mark
B. manufacturer mark
C. radial marking
D. SAE category mark

7. True or False.
If a bolt can be threaded completely through a nylon-insert nut, by hand, it may be re-used.

A. True
B. False

8. Select the best answer.
The design of internal and external tooth lock washers is intended to increases the ________ between the nut and the work piece and aids in maintaining tightness.

A. coefficient of friction
B. geodynamics
C. coalescence
D. surface tension

9. Select all that apply.
Identify the item(s) from the list below that describe how a flat washer's design contributes to proper fastener installation.

A. protect the surfaces
B. All listed items are correct
C. provide lubrication under the turning piece
D. spread the load over a larger surface area
E. None of the listed items are correct

10. True or False
Lock wire is used to keep a fastener or a series of fasteners properly tensioned.

A. True
B. False

11. Select the best answer.
What is the primary way to identify a legitimate (non-counterfeit) fastener?

A. grade marking
B. contact the Industrial Fastener Institute
C. documentation
D. manufacturer's marking

12. Select all that apply.
Identify any counterfeit fastener concern(s) listed below.

A. poor material composition
B. may lead to catastrophic failure
C. surface tension
D. low yield strength
E. color
F. cannot perform its intended function

13. Select the best answer.
When a fastener is properly tensioned, it stretches and applies a(n) ________ to the materials between its clamping faces.

A. coefficient of friction
B. axial tightening
C. clamping force
D. torque

14. Select the best answer.
You are required to install and torque some screws in a panel. The procedure requires the screws to be torqued to 8 foot pounds. You have a 0-75 in-lb. wrench available. Convert 8 foot pounds to inch pounds and indicate by your selection below if the available wrench is satisfactory.

A. 48 inch pounds, yes
B. 64 inch pounds, yes
C. 96 inch pounds, no
D. 80 inch pounds, no

15. True or False
Torque wrenches shall be selected so that the final torque value for the fastener(s) being tensioned falls within the upper two-thirds of the wrench range.

A. True
B. False

16. Select the best answer.
Fasteners should be tightened in at least ________ relatively equal increments.

A. six
B. four
C. two
D. none of the listed items

17. Select the best answer.
Select the item from the list below that best describes what would most likely result if you were to tension lubricated fasteners using a non-lubricated torque chart value.

A. nothing
B. under tensioning
C. would have to use a higher grade fastener
D. over tensioning

18. Select the best answer.

Where can you find the torque value for installing most UL approved devices for power distribution connections?
A. on the label
B. on the crane design drawings
C. in the equipment history file
D. on the schematic

19. Select the best answer.
What NEC article and table provides torque values for slotted head screws (#10 and larger)?

A. Article 110.14, Table 110.2
B. Article 610.14, Table 610.14(A)
C. Article 110.14, Informative Annex I, Table I.1
D. Article 430.52, Table 430.52

20. Select the best answer.
What NEC article and table provides torque values for slotted head screws (smaller than #10)?

A. Article 110.14, Table 110.1
B. Article 110.14, Table Informative Annex I, Table I.2
C. Article 610.14, Table 610.14(A)
D. Article 430.52, Table 430.52

21. Select the best answer.
An oxidation inhibitor should be applied to all fastener threads and the attaching conductors if the connection device is ________.

A. zinc plated
B. aluminum
C. copper
D. steel

SIGMA INSPECTION SIGNOFFS

Welcome and Learning Objectives

This module presents the approved journeyman level inspection items found on the MISR and AMISR. These items may be inspected by a mechanic or electrician in lieu of an inspector. Using the MISR to illustrate an example you will learn

- how to identify these inspection items, the manner in which to document the inspection results
- how to mark non-applicable items
- the procedure for documenting unsatisfactory items

To view the presentation, click the link located on the screen titled: Sigma Inspections. It may take more than a minute to load. Once the presentation is loaded it will run automatically. Navigational buttons are available in the presentation that allow you to pause or resume play, go back or move forward one screen, and view or hide the narration.

Sigma Inspections

Presentation

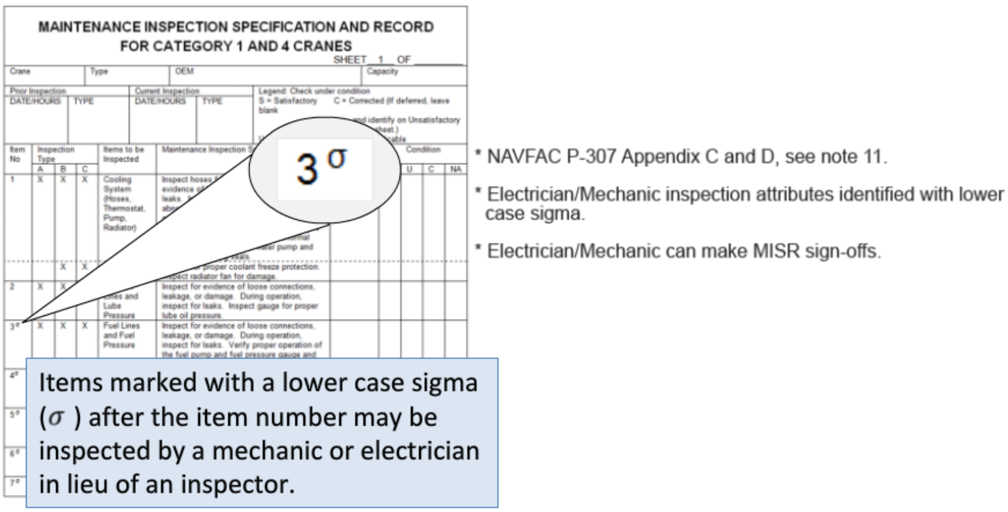
Screen 1: MISR, AMISR

Shown here are copies of the Maintenance Inspection Specification and Record for Category 1 and 4 cranes and the Annual Maintenance Inspection Specification and Record for Category 2 and 3 cranes which are commonly referred to as MISR and AMISR. For illustration purposes we show the MISR. The AMISR is completed the same way as the MISR. They both can be found in the NAVFAC P-307, Appendixes C and D.

These MISR's can be found in the NAVFAC P-307, Appendix C and D.

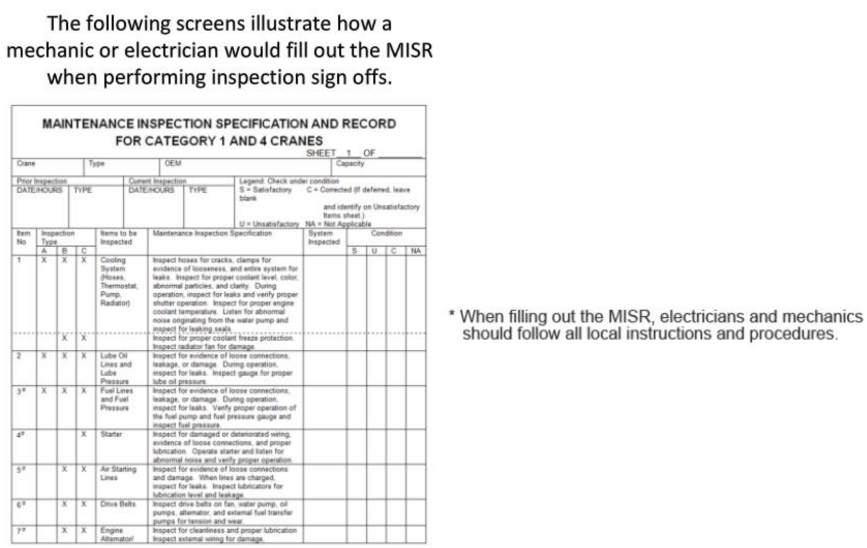
Screen 2: Appendix C & D, Note 11

Note eleven of each appendix states: "Items marked with a lower case SIGMA after the item number may be inspected by a mechanic or electrician in lieu of an inspector".



Screen 3: Local Procedures

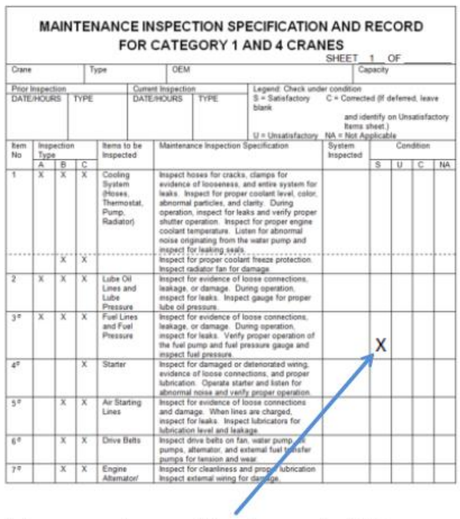
The following screens illustrate how the mechanic or electrician would fill out the MISR or AMISR when performing inspection sign-offs on any of the items marked with a lower case SIGMA.



Screen 4: Satisfactory Condition.

If the item is inspected and found to be satisfactory, mark the Satisfactory or "S" condition box for that item, as shown, or as required by local instruction.

For a satisfactory condition:



* When an item meets the inspection criteria:
* Record the "Satisfactory" condition on the MISR.

Mark the appropriate condition box on the MISR.

Screen 5: Signature Blocks.

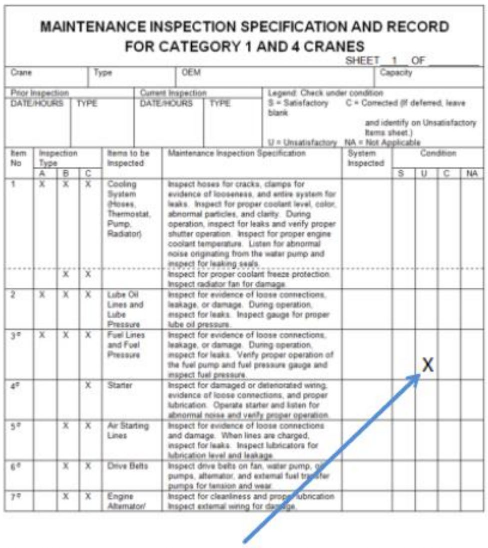
After completing the MISR inspections and marking the corresponding item(s) on the MISR, the mechanic or electrician will sign and date the MISR in the appropriate signature block.

* Make inspection sign-offs.
* Make sure to use correct signature block (see Mechanic or Electrician).
* Sign and date.

When complete sign and date in the applicable signature block (e.g., Mechanic or Electrician).

Screen 6: Unsatisfactory Condition.
If the item is inspected and found to be unsatisfactory, mark the Unsatisfactory or “U” condition box for that item, as shown, or as required by local instruction.

For an unsatisfactory condition:



MAINTENANCE INSPECTION SPECIFICATION AND RECORD FOR CATEGORY 1 AND 4 CRANES

SHEET 1 OF ____

Crane	Type	OEM	Capacity

Prior Inspection DATE/HOURS	Prior Inspection TYPE	Current Inspection DATE/HOURS	Current Inspection TYPE	Legend: Check under condition S = Satisfactory C = Corrected (If deferred, leave blank and identify on Unsatisfactory Items sheet.) U = Unsatisfactory NA = Not Applicable

Item No	Inspection Type A	Inspection Type B	Inspection Type C	Items to be Inspected	Maintenance Inspection Specification	System Inspected	Condition S	Condition U	Condition C	Condition NA
1	X	X	X	Cooling System (Hoses, Thermostat, Pump, Radiator)	Inspect hoses for cracks, clamps for evidence of looseness, and entire system for leaks. Inspect for proper coolant level, color, abnormal particles, and clarity. During operation, inspect for leaks and verify proper shutter operation. Inspect for proper engine coolant temperature. Listen for abnormal noise orignating from the water pump and inspect for leaking seals.					
		X	X		Inspect for proper coolant freeze protection. Inspect radiator fan for damage.					
2	X	X	X	Lube Oil Lines and Lube Pressure	Inspect for evidence of loose connections, leakage, or damage. During operation, inspect for leaks. Inspect gauge for proper lube oil pressure.					
3*	X	X	X	Fuel Lines and Fuel Pressure	Inspect for evidence of loose connections, leakage, or damage. During operation, inspect for leaks. Verify proper operation of the fuel pump and fuel pressure gauge and inspect fuel pressure.			X		
4*			X	Starter	Inspect for damaged or deteriorated wiring, evidence of loose connections, and proper lubrication. Operate starter and listen for abnormal noise and verify proper operation.					
5*		X	X	Air Starting Lines	Inspect for evidence of loose connections and damage. When lines are charged, inspect for leaks. Inspect lubricators for lubrication level and leakage.					
6*		X	X	Drive Belts	Inspect drive belts on fan, water pump, oil pumps, alternator, and external fuel transfer pumps for tension and wear.					
7*		X	X	Engine Alternator/	Inspect for cleanliness and proper lubrication. Inspect external wiring for damage.					

Mark the appropriate condition box on the MISR.

* When an item doesn’t meet the inspection criteria:

* Record the “Unsatisfactory” condition on the MISR.

Screen 7: Unsatisfactory Items Sheet.

All Unsatisfactory items shall be recorded on the Unsatisfactory Items Sheet.

1. The first block is for the MISR Item Number of the unsatisfactory item.

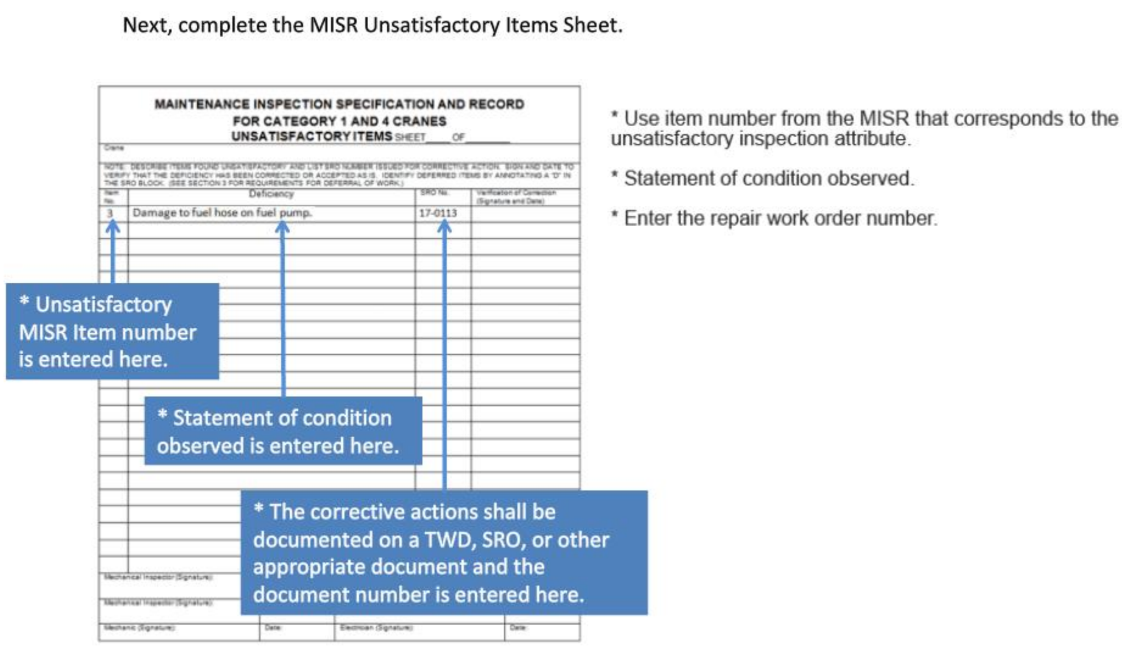
   a. To clarify, this item number corresponds with the unsatisfactory inspection attribute or item number on the MISR.

2. The next block is for the Deficiency.

   a. A brief yet concise statement of condition observed is entered here.

3. The next block is for the SRO number.

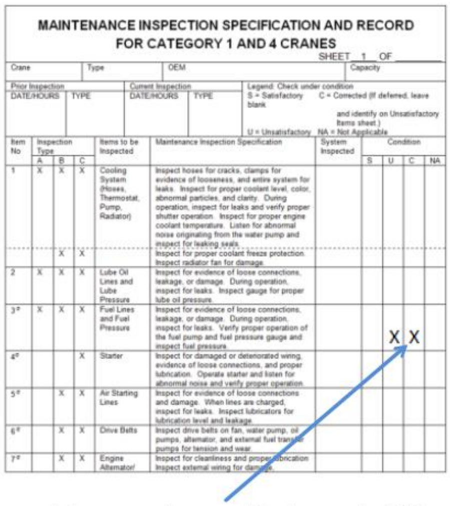
   a. Corrective action in terms of adjustments, repairs, or replacements of items shall be detailed on a TWD, SRO, or other appropriate document and the document number entered here.



Screen 8: Correction.

Once the item has been corrected, mark the Corrected or "C" in the appropriate condition box for that item, as shown, or as required by local instruction.

Once the **UNSATISFACTORY** item has been **CORRECTED…**



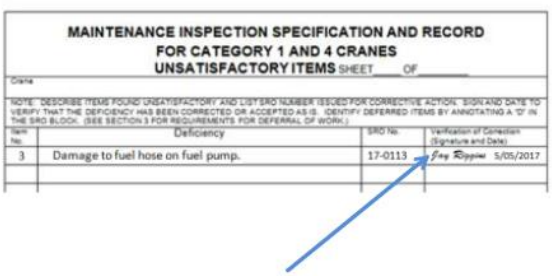
…mark the appropriate condition box on the MISR.

* Complete once the unsatisfactory item meets criteria.
* Mark MISR in the Corrected 'C' Condition Block.
* Next complete the MISR Unsatisfactory Items Sheet.

Screen 9: Correction Signature Block.

After marking the condition block as being corrected, sign and date the applicable Verification of Condition block on the Unsatisfactory Items sheet that corresponds to the corrected item.

Finally, sign the Unsatisfactory Items Sheet:

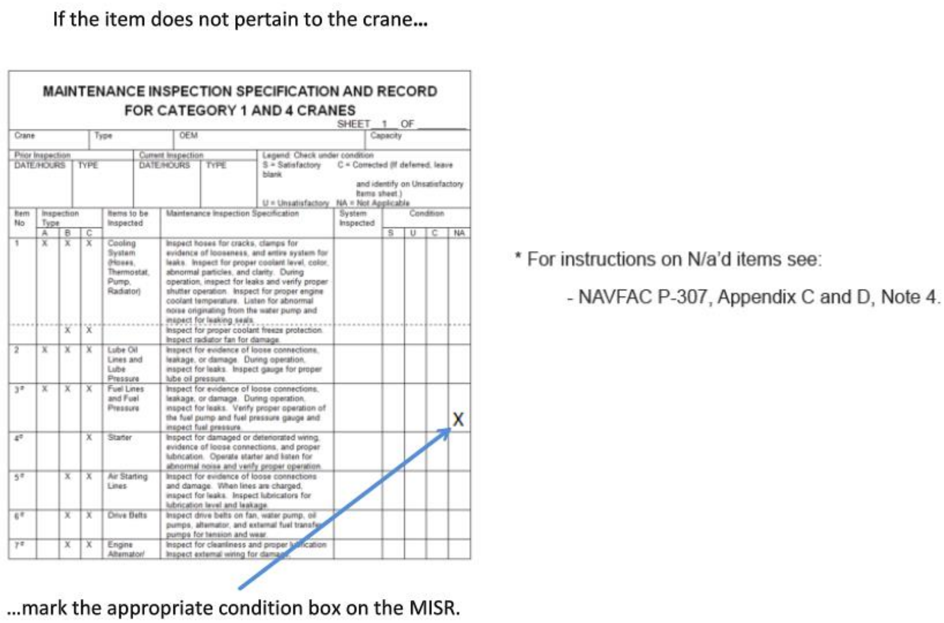


Verification of Correction signature and date is entered here.

* After marking the item 'C' on the MISR.
* Complete the MISR Unsatisfactory Item Sheet.
* Make verification signature and date.

Screen 10: N/A (not applicable).

Where “NA” is used to note that an inspection criterion does not apply due to a reason other than the component or feature is not on the crane or inspection is not required due to the type of inspection, follow as required, Note four of Appendix C or D of the NAVFAC P-307 and all local instructions. Mark as Not Applicable or “NA” in the condition box for that item, as shown.



MAINTENANCE INSPECTION SPECIFICATION AND RECORD FOR CATEGORY 1 AND 4 CRANES

SHEET 1 OF ____

Crane	Type	OEM	Capacity

Prior Inspection DATE/HOURS	Prior Inspection TYPE	Current Inspection DATE/HOURS	Current Inspection TYPE	Legend: Check under condition
				S = Satisfactory C = Corrected (If deferred, leave blank and identify on Unsatisfactory Items sheet.) U = Unsatisfactory NA = Not Applicable

Item No	Inspection Type A	B	C	Items to be Inspected	Maintenance Inspection Specification	System Inspected	Condition S	U	C	NA
1	X	X	X	Cooling System (Hoses, Thermostat, Pump, Radiator)	Inspect hoses for cracks, clamps for evidence of looseness, and entire system for leaks. Inspect for proper coolant level, color, abnormal particles, and clarity. During operation, inspect for leaks and verify proper shutter operation. Inspect for proper engine coolant temperature. Listen for abnormal noise originating from the water pump and inspect for leaking seals.					
		X	X		Inspect for proper coolant freeze protection. Inspect radiator fan for damage.					
2	X	X	X	Lube Oil Lines and Lube Pressure	Inspect for evidence of loose connections, leakage, or damage. During operation, inspect for leaks. Inspect gauge for proper lube oil pressure.					
3*	X	X	X	Fuel Lines and Fuel Pressure	Inspect for evidence of loose connections, leakage, or damage. During operation, inspect for leaks. Verify proper operation of the fuel pump and fuel pressure gauge and inspect fuel pressure.					X
4*			X	Starter	Inspect for damaged or deteriorated wiring, evidence of loose connections, and proper lubrication. Operate starter and listen for abnormal noise and verify proper operation.					
5*		X	X	Air Starting Lines	Inspect for evidence of loose connections and damage. When lines are charged, inspect for leaks. Inspect lubricators for lubrication level and leakage.					
6*		X	X	Drive Belts	Inspect drive belts on fan, water pump, oil pumps, alternator, and external fuel transfer pumps for tension and wear.					
7*		X	X	Engine Alternator/	Inspect for cleanliness and proper lubrication. Inspect external wiring for damage.					

NOTES

SIGMA Inspection Signoffs Knowledge Check

Online questions may appear in a different order that those shown below.

1. Select the best answer.
The MISR and the AMISR can be found in what section of the NACVFAC P-307?

A. Appendix A and B
B. Appendix B and C
C. Appendix C and D
D. Appendix D and E

2. Select the best answer.
The mechanic and electrician inspection attributes are identified how?

A. Only on the first page of the MISR after the signature block
B. Only by those identified with a lower case SIGMA after the item number
C. Only on the first page of the AMISR after the signature block
D. Only on the first page of the MISR

3. True or False
If an item is found unsatisfactory then you must mark the item unsatisfactory and complete the MISR or AMISR unsatisfactory items sheet.

A. True
B. False

4. True or False
When completing the MISR or AMISR unsatisfactory sheet, you must describe in detail the problem and signoff as complete.

A. True
B. False

5. Select all that apply.
After correcting the unsatisfactory item, you…

A. Mark the item on the MISR as complete
B. Complete the MISR unsatisfactory items sheet
C. Review the test procedure
D. sign and date the verification of correction

NAVFAC Naval Facilities Engineering Command
NAVY CRANE CENTER

CRANE ELECTRICIAN COURSE EVALUATION SHEET

Student Name: ____

Command/Activity/Organization: ______________________________________

Instructor: ______________________________ Date: ________________

Directions: To assist in evaluating the effectiveness of this course, we would like your reaction to this class. Do not rate questions you consider not applicable.

Please rate the following items:	Excellent	Very Good	Good	Fair	Poor
Content of the course met your needs and expectations.					
Content was well organized.					
Materials/handouts were useful.					
Exercises/skill practices were helpful.					
Training aids (slides, videos, etc.) were used effectively.					
Instructor presented the material in a manner, which was easy to understand.					
Instructor was knowledgeable and comfortable with the material.					
Instructor handled questions effectively.					
Instructor covered all topics completely.					
Probability that you will use ideas from the course in your work.					
Your opinion of the course.					
Your overall opinion of the training facilities.					

What were the key strengths of the training? How could the training be improved? Other comments?

____

____

____

____

List other training topics in which you are interested: ______________________________

____

____

Note: If you would like a staff member to follow up and discuss this training, please provide your phone number____