CENTER DIRECTIVES MANAGEMENT SYSTEM
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# Chapter 11 – Electrical Safety (REDACTED)

## 11.1 Introduction

### 11.1.1 Purpose

The purpose of this chapter is to provide the practical "Work Rules" for electrical work performed at Ames Research Center. This chapter will provide one of the means of safeguarding workers and the public from injury.

### 11.1.2 Applicability

This manual is applicable to: (1) all Ames Employees; and (2) all persons and entities who agree in writing to comply with this manual.

### 11.1.3 Scope

This chapter covers the Ames Research Center requirements and procedures for designing a safe system and maintaining safe working conditions for personnel, who operate, maintain, or install electrical and related mechanical apparatus and equipment.

## 11.2 Conformance Codes and Regulations

### 11.2.1 Applicable Standards and Codes

The provisions of the following standards and codes apply to all electrical work done on Ames Research Center premises and must be followed:

1. Occupational Safety and Health Act (OSHA) - The Act covers conditions, practices, and operations to assure safe and healthful work places.
2. National Electrical Code published by the National Fire Protection Association (NFPA-70) - This standard covers the requirements of a safe design, installation, repair and maintenance of electrical systems in residential and industrial facilities.
3. National Electrical Manufacturers Association (NEMA) - These standards cover electrical power equipment including standard ratings, performance, testing, manufacturing, and marking.
4. Electronics Industries Association (EIA) - These standards cover electronic-type electrical equipment and components.
5. Insulated Power Cable Engineers Association (IPCEA) - These standards cover insulated power, control, and communication cable.
6. Institute of Electrical and Electronic Engineers (IEEE) - These standards consist of technical reports that set out testing procedures generally used in electrical power generation, distribution, and utilization.
7. American National Standards Institute (ANSI) - A guide to the manufacture, handling, and performance of electrical equipment.

# 11.3 Work Requirements

## 11.3.1 Definitions

### 11.3.1.1 Low Voltage

Electrical circuits at or below 600 V.

### 11.3.1.2 High Voltage

Electrical circuits above 600 V.

### 11.3.1.3 High Voltage Supervisor

Designated by the Plant Engineering Branch.

## 11.3.2 General Requirements

- Consider all electrical apparatus energized until properly tested by a qualified worker and verified by partner.
- Workers shall not work alone on energized electrical equipment.
- Do not use metal ladders when working on electrical equipment.
- Removal of switchgear panels or panel door barriers from energized circuits above 600 V for inspection, data gathering or infrared testing of distribution bus must be authorized by the High Voltage Supervisor or designated alternate.
- Use appropriate personal protective equipment (PPE). Do not wear watches, rings, or other conductive apparel where they may present a hazard. Minimum acceptable PPE is defined in section 11.3.3.
- Lockout and Tagout the equipment before service or maintenance to avoid unexpected energization of circuits, startup of equipment, or the release of stored energy, which could injure you or someone else.
- Personnel shall immediately report to their Supervisor anyone that they believe to be under the influence of drugs or intoxicating liquor.
- If workers are in doubt of any assigned work, the workers shall not proceed and shall request instructions from the supervisor or person in charge.
- Workers shall heed warning signs and signals and warn others who are in danger or in the vicinity of energized equipment.
- When performing hazardous operations such as high voltage switching, each worker shall confirm oral messages from co-workers prior to all operational steps.
- Ground Fault Circuit interrupters shall be used on all temporary electrical lines, cables, and cords.
- There are several types of power receptacles for various voltages, phases and currents at Ames Research Center. Be sure to use proper receptacle for each application. See appendix for information on proper receptacles that are used at Ames Research Center.
- Measurement equipment shall be tested before and after use to verify proper operation.

## 11.3.3 Specific Requirements

### 11.3.3.1 Live Work Guidelines

Whenever possible, electrical work shall be performed on de-energized circuits. When required, operations on live circuits such as trouble shooting and monitoring can be performed.

### 11.3.3.2 Personnel Protection Equipment (PPE)

Each organization responsible for working on electrical systems must establish policies and procedures for personnel protection equipment. APG 1700.1 Chapter 6 defines general guidelines. Specific minimum PPE requirements for electrical work PPE is presented below.

The minimum required PPE for any electrical work is:

- Flame Retardant or Natural Material Outer Clothing & Underwear
- No Jewelry (watches, rings, or other conductive apparel)
- Eye protection
- Safety shoes

Minimum Additional Required PPE

| Operation | NFPA Approved Flash Suit (with hood) | High Voltage Class 2 Gloves | Low Voltage Gloves | Hardhat | Safety Harness |
|---|---|---|---|---|---|
| Work on **energized** circuits – between 50 & 600 V | | | X | | |
| **Overhead** Switching: Manual operation from bucket truck of load break fused air switches - 12 kV | | X | | X | X |
| **Overhead** Switching: Remote operation from ground level of NO Load break (but energized) air switches - primarily 115 kV, 13.8 kV, and 6.9 kV | | X | | X | |
| Outside Ground Level Operation of air, SF6 and oil switches - 13.8 kV, 12 kV, 6.9 kV, 2.4 kV operated **manually** | | X | | | |
| **Enclosed** Ground Level Operation of air, SF6 and oil switches - 13.8 kV, 12 kV, 6.9 kV, 2.4 kV operated **manually** | X | X | | X | |
| **Underground** Switching Operation of air, SF6 and oil switches - 13.8 kV, 12 kV, 6.9 kV, 2.4 kV -Operated **manually** | X | X | | X | X |
| **Remote** operation of SF6 switches | | | | | |
| **Enclosed/indoors** Raising and Lowering (Racking In and Out) of Cubicle Mounted vacuum, SF6, oil and air circuit breakers - 13.8 kV, 12 kV, 6.9 kV, 2.4 kV -**energized** but with no load | X | X | | X | |
| **Outdoors** Raising and Lowering (Racking In and Out) of Cubicle Mounted vacuum, SF6, oil and air circuit breakers - 13.8 kV, 12 kV, 6.9 kV, 2.4 kV -**energized** but with no load | | X | | | |
| Work on High Voltage Components **De-energized**, locked-out/tagged-out, and grounds properly applied | | | | | |
| Inspection of High Voltage Components **Energized** | Appropriate PPE must be defined for each situation | | | | |

#### 11.3.3.2.1 Gloves Voltage Classes

| Glove Class | Test Voltage (kV) | AC Max. Use Voltage * |
|---|---|---|
| 0 | 5 | 1,000 |
| 1 | 10 | 7,500 |
| 2 | 20 | 17,000 |
| 3 | 30 | 26,500 |
| *Per ASTM D120-02 | | |

#### 11.3.3.2.2 Testing of Protective Devices

Each organization responsible for the use and maintenance of protective devices shall define and follow a process to assure that the equipment meets the following requirements.

- Protective devices, hot sticks, and voltage testers shall be tested every 12 months to insure that they are in safe working condition.
- Insulating gloves, sleeves, blankets, mats and hot sticks shall be inspected before use.
- Insulating gloves and sleeves shall be tested every 6 months by a certified testing firm or replaced with new ones. ANSI/ASTM D120-02 outlines electrical testing procedures for rubber gloves. Sleeve testing procedures are outlined in ANSI/ASTM 1051-02.
- Body harnesses and lanyards and other personnel equipment shall be inspected and tested every 12 months to insure that they are in safe working condition.

### 11.3.3.3 Storage of Protective Devices

All protective equipment must be properly stored when not in use.

- Gloves must be stored in proper glove bags
- Hot sticks must be stored in a manner to keep them clean and dry.

### 11.3.3.4 System Documentation

System documentation, showing the arrangement, location, and wiring of the electric-supply equipment shall be maintained on the job site and readily available to authorized personnel for that portion of the system for which they are responsible.

### 11.3.3.5 Hard Hat Area

If the area is designated as a hard hat area, then all workers shall wear an approved hard hat.

### 11.3.3.6 Welding

Welding shall not be allowed in the immediate vicinity of electrical equipment unless the equipment is locked-out and disconnected from the power source. A Hot Work Permit must be obtained from Code QH (Safety Health and Medical Services Division--refer to APG 1700.1, Chapter 20) prior to any welding.

### 11.3.3.7 Fall Protection

Workers working in an elevated position shall use adequate fall protection controls.

### 11.3.3.8 Lockout/Tagout

Lockout/Tagout (LOTO) controls are required when servicing or maintaining machines or equipment, which have the potential for unexpected energization, startup, or release of stored energy. Each organization responsible for working on electrical systems must establish policies and procedures for LOTO of equipment. APG 1700.1 Chapter 31 defines the requirements for the LOTO program.

A typical LOTO shutdown sequence is:

- Verify that it is safe to shut down equipment
- Perform normal shutdown
- Isolate and lock out energy sources
- Enter required information on tag and apply tag
- Release or block stored energy
- Verify Lockout (attempt to restart/operate equipment)

### 11.3.3.9 Confined Space Entry

Each organization responsible for working on electrical systems must establish policies and procedures for confined space entry, which meets the requirements of APG 1700.1 Chapter 26.

### 11.3.3.10 Portable Equipment Grounding

The cases of all portable electrical motor-driven hand tools must be grounded by use of standard three-prong plugs and receptacles. The cases or frames of all other electrical equipment supplied with 50 V or greater must be connected to ground, except as follows:

- Devices operated solely from self-contained batteries.
- Devices that have cases and all exposed parts protected by insulating material (Double Insulated).
- Devices supplied with less than 150 V for which the Ames Safety, Health and Medical Services Division has granted exceptions.

### 11.3.3.11 Temporary Wiring

Temporary wiring is allowed in the following instances:

- During the period of construction, remodeling, maintenance, repair, or demolition of buildings, structures, equipment, and similar activities;
- During emergencies and for tests, experiments and developmental work; and
- For a period not exceed 90 days for holiday decorative lighting and similar purposes.

Temporary wiring shall be removed immediately upon completion of construction or purpose for which the wiring was installed.

### 11.3.3.12 Extension Cords

Buildings often lack sufficient number of electrical receptacles, or the location of receptacles may not suit occupant requirements. Where feasible, consideration should first be given to relocating the electrical equipment closer to a wall receptacle or installing a wall receptacle. Extension cord usage shall abide by the restrictions for temporary wiring.

Where extension cords are utilized, they shall not be:

- Used as a substitute for the fixed wiring of a structure;
- Routed through holes in walls, ceilings, or floors;
- Run through doorways, windows, or similar openings;
- Attached to buildings surfaces; or
- Concealed behind building walls, ceilings, or floors.

Additional Safety Practices

- Use only Underwriters Laboratories (UL) or other testing laboratory-approved electrical devices.

- An extension cord shall have adequate current-carrying capacity to handle the maximum current draw of the electrical device serviced. Compare the ampere rating of the electrical device with the rating of the extension cord.
- High current equipment (e.g., microwave ovens, space heaters, and coffee pots) shall be plugged directly into wall receptacles.
- Daisy chaining (i.e., linking two or more extension cords) is prohibited.
- Extension cords must be of the three-pronged grounded variety, and suitable for the conditions of use and location.
- A surge protector power strip is a special type of extension cord that is intended to protect computers and related equipment from damaging power fluctuations. Surge power strips are allowed for use with computers and related equipment, and should not be used with other electrical equipment.

### 11.3.4 Above 600 Volts (High Voltage)

### 11.3.4.1 Grounding of Equipment

#### 11.3.4.1.1 Protective Grounding and Short Circuiting

- The circuit or equipment must be de-energized, isolated, tagged and locked before protective grounds are attached.
- All protective-grounding cables must first be attached to a common point on the metal structures or connected together with a jumper not smaller than 2/0 copper. In all cases the ground cables must be applied to both ground and short-circuits all the conductors of the circuit.
- Protective grounds must be placed on all sides of the work where there is a possible source of power (including wire crossings and parallel lines) and as close to the point of the work as possible. Additional grounds must be placed where necessary to reduce static charges or induced voltage from adjacent lines.
- Use Only grounding devices approved by ANSI
- All grounding devices must be removed prior to energizing the circuit.

#### 11.3.4.1.2 Grounding of Underground Cables

Protective grounding of conductors making up ungrounded cables cannot always be done at the point of work. In such cases, the grounds must be attached at the nearest location where the conductors can be reached, in accordance with protective grounding instructions above.

#### 11.3.4.1.3 Grounding of Current and Potential Transformers

- Current transformer case and secondary must be grounded.
- Where more than one set of current transformer secondaries are connected electrically, a ground point must be selected that provides grounding for the network.
- The current transformer secondary must never be opened while the transformer is energized. The current transformers must be connected to a load or shorted at all times when the system is energized.
- The case and one wire on the low voltage side of a potential transformer must always be grounded before energizing the transformer.

#### 11.3.4.1.4 Grounding of Power Capacitors

- All individual power capacitor banks must be grounded except the capacitors installed in banks on specially insulated mounting racks. In the case of a capacitor bank mounted on a specially insulated rack, the rack also must be grounded before working on the bank.

- In order to work on any capacitor unit or bank, the capacitor or capacitors must be removed from service and grounded in the approved manner.

#### 11.3.4.1.5 Grounding of Coupling Capacitors

- The pedestal base of all coupling capacitors must be permanently grounded.
- Before any work is performed on the external part of a coupling capacitor, it must be de-energized, each section discharged to ground, and then grounded at the line side of the top section. In discharging the sections, first attach the ground clamp to the station ground and then use a ground stick to touch the ground conductor to the bottom of each section.

### 11.3.4.2 Working in Underground Utilities

#### 11.3.4.2.1 General Requirements

- Ames Confined Space entry Permit requirements must be met for work performed in all underground utilities. Refer to APG 1700.1, Chapter 26 for details.
- When manholes, handholes, or vault gratings are open, suitable barriers or guards shall be erected around the openings. Adequate warning lights shall be provided during hours of darkness. In addition, safety cones, barricades and warning signs must be used to direct vehicular and pedestrian traffic around such openings.
- Manholes shall be entered by means of ladder when practicable.
- Manhole covers and gratings must be properly seated when replaced.
- Employees shall use only approved lighting units for illumination when working underground.
- Air driven tools used around energized cables shall be grounded.

#### 11.3.4.2.2 Underground Cables

- Electrical power system cables shall not be spliced when energized.
- When cables are to be de-energized to permit work on them the following are required:
  1. Identify cables by tags, ducts, and/or records
  2. Tag and ground the cables
  3. Test for voltage with a remote-operated piercing tool. Wear high voltage gloves and safety glasses when performing the piercing operation.
- All cables in manholes must be considered a source of potential shock. Tests must be made to make sure there is no voltage between their outer sheaths and ground.
- Cable movement of energized cable shall be minimized.
- Even though cables are shown to have no potential between their outer sheaths and ground, contact should be avoided unless necessary to complete the work. High voltage gloves must be worn unless cables have been cleared as required above.
- When cables are being pulled into manholes, a physical barrier must be provided to prevent contact between existing energized cables and the new cables, cable pulling equipment, and personnel.

### 11.3.4.3 Racking High Voltage Circuit Breakers

There are various manufacturer requirements for RACKING-IN and RACKING-OUT high voltage circuit breakers. This chapter will not cover the specific rack-in and rack-out procedures. However, it will cover the **minimum safety requirements** when the workers are racking circuit breakers.

The organizations responsible for racking high voltage circuit breakers shall have defined policies and procedures for these operations. These organizations shall define and implement

certification training. Certified operators who have completed the appropriate training shall be the only personnel who perform racking operations.

- Two certified electricians or one certified electrician and a certified observer are required to perform the **"Rack in or Rack out"** of the circuit breaker.
- **DO NOT** rack the breaker into operating position with the closing springs charged or fully compressed.
- **Clear all personnel** from the immediate and adjacent areas where blast effects might be present and rope off area.
- When racking in an enclosed area wear **NFPA approved flash suits** including coveralls flash protection jacket and pants, hood, safety shoes and high voltage gloves.
- Wear Safety Glasses, hard hat and carry portable radio.

#### 11.3.4.4 High Voltage Switching

The organizations responsible for high voltage switching shall have defined polices and procedures for these operations.

##### 11.3.4.4.1 Re-Energizing Equipment

When re-energizing equipment, written and approved procedures shall be followed. The procedures shall require at least the following:

- Visual inspection of the area that has been shutdown to ensure that all tools, electrical jumpers, test devices, etc have been removed.
- Warn all workers to stay clear of all circuits and equipment to be energized.
- Remove all grounds and grounding conductors.
- Each worker who applied a lock and tag shall personally remove them. If the worker is not available, the supervisor or manager will implement the procedures outlined in APG 1700.1, Chapter 31, Section 31.11-Emergency Removal of LOTO devices.
- Test for absence of any shorts or grounds.

### 11.3.5 Construction Permits

A construction permit must be obtained prior to construction, modification, demolition or replacement of any electrical systems. Construction permit requirements are covered in Ames Management Instruction AMI 8829.1. For permit process assistance contact the Construction Permit Office at extension **REDACTED** or the Ames Facility Engineering Branch Office at extension **REDACTED**.

#### 11.3.5.1 Underground Systems

No excavation may be made for any subsurface work without first obtaining clearance from the Ames Facilities Engineering Branch and Plant Engineering Branch.

- The clearance provided must ensure that the proposed work or design is free from any obstruction or interference with any existing underground system or any other systems scheduled to use the same area.

## 11.4 Training Requirements

### 11.4.1 Qualification of Workers

Each organization responsible for working on electrical systems must establish policies and procedures to define qualification of their workers. 29 CFR 1910.331 through 0.335 defines safety-related work practices for the qualified and unqualified workers as:

Qualified Workers:

1. Have been trained in avoiding the electrical hazards of working on or near exposed energized parts.
2. Have the knowledge to distinguish between live parts and other parts of electrical equipment.
3. Have skill and techniques to determine nominal voltage and exposure clearance distances.
4. Have training to handle hot line tools and is familiar with the electrical system.

Unqualified Workers:

1. Have little or no training in avoiding the electrical hazards or working on or near exposed energized parts.
2. Do not normally work on or near electric-supply lines and equipment, but whose work brings them into these areas for certain tasks, shall proceed with this work only when authorized by a qualified person.

### 11.4.2 Required Training

All Ames personnel and Ames on-site or off-site Contractor who work with electrical equipment at the Ames Research Center, are required to complete the minimum training defined below in accordance with job requirement and OSHA regulations. The training shall be completed prior to commencement of work.

| Required Training | How Often |
|---|---|
| Lockout/Tagout | Every 3 Years |
| Personnel Protection Equipment | Every 3 Years |
| Electrical Safety Training* | Annually |

*Required for all personnel who enter confined spaces that contain electrical system feeder cables and equipment.

### 11.4.3 Recommended Training

All Ames personnel and Ames on-site or off-site contractors who work with electrical equipment at the Ames Research Center should complete the following training:

| Recommended Training | How Often (Recommended) |
|---|---|
| Confined Space Entry | Annually |
| CPR | Annually |
| First Aid | Every 3 Years |
| Asbestos Awareness | Every 3 Years |
| PCB Awareness and Handling | Every 3 Years |
| Lead Awareness | Every 3 Years |

## 11.5 Electrical System Documentation Requirements

### 11.5.1 Areas of Responsibility

The Ames Facilities Engineering Branch shall maintain documentation, which delineates areas by branch responsibilities for the high voltage distribution systems. The Ames Electric Power Office (EPRO) shall approve this document.

### 11.5.2 System Design Drawings

The design engineer of each electrical system is responsible for determining what drawings are required to conform to safety requirements in setting up the necessary drawings for maintaining safe operations of the final system. The electrical drawings for each system shall include, as a minimum, the following:

1. A complete single-line diagram.
2. A complete wiring, elementary, and interconnection wiring links showing connections at each terminal strip where connections are made.
3. Equipment location plan.
4. Control criteria document that provides the required control and safety interlock information needed to provide a safe and practical control.
5. Current drawings must be retained in the Ames Facilities Engineering Branch Engineering Documentation Center (EDC).
6. Complete functional diagram that shows the essentials of the mechanical and electrical system together with a clear explanation of the system operation.
7. A complete schematic or elementary wiring diagram of each piece of equipment.
8. Wiring diagram of each unit of equipment together with an interconnection drawing linking all equipment showing connections at each terminal strip where connections are made.

### 11.5.3 Drawing Distribution

Ames Facilities Engineering Branch or its designee shall provide updated drawings to the users and the Ames Plant Engineering Branch.

### 11.5.4 High Voltage Switching Diagrams

The Ames Facilities Engineering Branch shall maintain master sets of the switching diagrams for the high voltage power distribution system.

### 11.5.5 Underground Utilities Drawings

Ames Facilities Engineering Branch shall maintain a complete set of master drawings along with appropriate updates of duct banks and underground utility systems.

### 11.5.6 Building Drawings

Drawings of each building power distribution system must be maintained by the Ames Facility Engineering Branch and must include:

1. Plot plan of each building showing the partitions and physical locations of all panelboards, motor control centers, main distribution panels, and unit power substations.
2. A complete one-line (single-line) power distribution diagram of the electrical power flow from the building unit substations to the building load buses showing the circuit breakers controlling the identified loads.

3. A schedule of the circuit handled of each circuit breaker in each panelboard must be maintained. (Persons adding or deleting circuits must change this schedule to show the modifications.)

### 11.5.7 On-Site Drawings

An applicable set of System Design Drawings must be maintained on the job site, in each electrical substation and at each building or facility.

### 11.5.8 Configuration Management

The Ames Facility Engineering Branch shall maintain the configuration plan for the Ames Electrical System. It shall meet the requirements of 53.FE.0103 Code FE Systems Engineering Division Configuration Management Plan Template.

## 11.6 Operation and Maintenance Requirements

### 11.6.1 General

#### 11.6.1.1 Color Coding - Indicating Lights

All workers shall use the following Color Coding for indicating lights to be installed in the control rooms, switchgear, motor control centers, panels, etc. If a specific facility does not use this color scheme, it must specifically document the color scheme to be used.

Color caps on indicating lights designating the conditions or position of the contacts on circuit breakers or switches must conform to the following:

| | |
|---|---|
| Red | Contacts Closed (energized) |
| Green | Contacts Open (not energized) |
| Amber | Contact Automatically Tripped Open |

Color caps on indicating lights designating the position of a control valve that allows flow or block flow must conform to the following:

| | |
|---|---|
| White | Allows Flow (Flow) |
| Blue | Blocks Flow (No Flow) |

#### 11.6.1.2 Color Coding - Wiring

The color-coding specified below must be used for new wiring installed at NASA-Ames.

##### 11.6.1.2.1 At or Below 600 V

| Conductor | 120/208/240 V | 277/480 V |
|---|---|---|
| Phase A | Black | Brown |
| Phase B | Red | Orange |
| Phase C | Blue | Yellow |
| Neutral | White | White |
| Equipment Grounds | Green | Green |

#### 11.6.1.2.2 Above 600 Volts

| Conductor | 6,900 V | 13,800 V |
|---|---|---|
| Feeder Termination @ Switchgear and Transformers | | |
| Phase A | Black | Black |
| Phase B | Red | Red |
| Phase C | Blue | Blue |
| Feeder Termination @ Underground Switches | | |
| Phase A | Black | Black |
| Phase B | Red | Red |
| Phase C | Blue | Blue |

### 11.6.1.3 Accessibility

All fixed electrical equipment must be accessible for maintenance, repair, and de-energization. The minimum clear space around electrical equipment as indicated by yellow markings on the floor shall be three feet and must be kept clear.

High-voltage (above 600V) circuit breaker switchgear requires six feet of clear space at the front and three feet at the rear. Motor control centers, panel boards, and terminal cabinets require a minimum of three feet in front.

### 11.6.1.4 Working Clearances

#### 11.6.1.4.1 At or Below 600 Volts AC

Sufficient access and working space shall be provided and maintained about all electric equipment (from 50 V to 600 V) to permit ready and safe operation and maintenance at Ames. Distance shall be measured from the live parts, if such are exposed, or from the enclosure front or opening if such are enclosed.

| Voltage to Ground | Condition* | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 0 to 150 V | 3 ft | 3 ft | 3 ft |
| 150 to 600 V | 3 ft | 3 ft | 4 ft |

#### 11.6.1.4.2 Above 600 Volts AC

Working clearances shall be in accordance with table in below:

| Voltage to Ground (Volts) | Condition* | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 601 to 2,500 | 3 ft | 3 ft | 3 ft |
| 2,501 to 9,000 | 4 ft | 5 ft | 6 ft |
| 9,001 to 25,000 | 5 ft | 6 ft | 9 ft |
| 25,001 to 75,000 | 6 ft | 8 ft | 10 ft |
| Above 75,000 | 8 ft | 10 ft | 12 ft |

***Where the Conditions are as follows**

| | |
|---|---|
| Condition 1 | Exposed energized parts on one side and no energized or grounded parts on the other side of the workspace. Or, Exposed energized parts on both sides effectively guarded by suitable wood or other insulating materials. |
| Condition 2 | Exposed energized parts on one side and grounded parts on the other side of the workspace. |
| Condition 3 | Exposed energized parts on both sides of the workspace with the operator between. |

### 11.6.1.4.3 In the Substations

| Nominal Voltage between Phase to Ground or Phase to Phase (V) | Elevation |
|---|---|
| 1,001 to 7,500 | 8 ft 6 in. |
| 7,501 to 35,000 | 9 ft |
| 35,001 to 110,000 | 9 ft to 11 ft |
| 110,000 to 120,000 | 11 ft to 12 ft |

### 11.6.1.4.4 Approach Distance to Exposed Energized Parts

Qualified workers shall not approach or take any conductive object, within the "approach distance" to an exposed energized part in switchgear, panelboards, electrical substations, or rotation equipment shown below.

| Voltage Range | Approach Distance |
|---|---|
| 0 to 50 V | Avoid Contact |
| 50 to 300 V | Avoid Contact |
| 300 to 750 V | 1 ft |
| 750 to 15,000 V | 2 ft 2 in. |
| 15.1 kV to 36 kV | 3 ft |
| 36.1 kV to 46 kV | 3 ft 6 in. |
| 46.1 kV to 121 kV | 4 ft |
| 121 kV to 140 kV | 4 ft 6 in. |

**Unqualified workers** as defined by OSHA shall maintain a minimum clearance of 10 ft from energized lines.

### 11.6.1.5 High Voltage Verification Test Conditions

| Equipment Voltage (E) (Phase to Phase) | Maximum High Potential Test Voltages (Phase to Ground) | | | | |
|---|---|---|---|---|---|
| | AC Old Equipment 0.5 x (2 x E + 1000) | AC New Equipment 2 x E + 1000 | DC Old Equipment 0.5 x 1.6 x (2 x E + 1000) | DC New Equipment 1.6 x (2 x E + 1000) | Polarization Index DC Test Voltage |
| 13-15 kV | 14 kV | 29 kV | 22 kV | 46 kV | 5 kV |
| 6.9-7.2 kV | 7 kV | 15 kV | 11 kV | 24 kV | 2.5 kV |
| 3.7-4.16 kV | 4 kV | 8 kV | 6 kV | 12 kV | 1.0 kV |
| 2.4 kV | 3 kV | 6 kV | 4.8 kV | 9.6 kV | 1.0 kV |
| 1-1.2 kV | 1.5 kV | 3 kV | 2.5 kV | 5 kV | 1.0 kV |
| 720-800 V | 1 kV | 2.5 kV | 2 kV | 4 kV | 500 V |
| 440-480 V | 600 V | 600 V | 600 V | 600 V | 500 V |

**Notes:**

1. The values of the test voltages in the chart were determined by investigations of various standards and recommendations of large manufacturers (ASA-C52, IEEE, Westinghouse, General Electric, and Inter ASN Test Standard) to provide a meaningful test without possible damage of equipment.
2. A polarization index or dielectric absorption ratio is determined by calculating the ratio of resistance taken one (1) minute after test voltage application to the resistance taken after a 10-minute interval. If the ratio is greater than three (3), the insulation is considered acceptable (good). A lower value indicates presence of moisture or dirt.
3. Transformers should not be tested with DC. AC tests are more meaningful.
4. DC tests are performed with voltages being measured in equal steps and at timed intervals with the results (leakage current vs. test voltage) being plotted as the test progresses. An upward change on the slope of the curve is an indication of potential failure breakdown of the insulation being tested. The test should be terminated at this point.

#### 11.6.1.5.1 Cranes and Lifting Equipment (Work Adjacent to Electrical Line)

Any overhead wires and cables shall be considered to be energized line unless it has been visibly grounded and Ames Plant Engineering Branch indicates that it is not an energized line.

A person shall be designated to observe clearance of the equipment and give timely warning for all operations where it is difficult for the operator to maintain the desired clearance by visual means.

When electrical distribution and transmission lines have been energized at point of work, the equipment or machines shall be operated proximate to energized power lines per distance identified below:

| | |
|---|---|
| For lines rated 50 kV or below: | Minimum clearance between the lines and any part of the crane or load shall be 10 ft. |
| For lines rated over 50 kV: | Minimum clearance between the lines and any part of the crane or load shall be 10 ft plus 0.4 in. for each 1 kV. |

| | |
|---|---|
| Crane with No Load and Boom Lowered: | The equipment clearance shall be a minimum of:<br>▪ 4 ft for voltage less than 50 kV<br>▪ 10 ft for voltages over 50 kV<br>▪ 16 ft for voltages up to and including 750 kV. |

## 11.6.2 Facilities and Equipment

### 11.6.2.1 General Requirements

Each facility must have written operating and maintenance procedures to ensure the safety of personnel and the equipment. These procedures must include safety precautions and emergency actions required. At least annually, these procedures shall be reviewed and updated as needed.

### 11.6.2.2 Installation or Major Repair

When working on the new installation, repair or overhaul of electrical equipment or system, the work shall be coordinated with the Ames Facility Service Manager (FSM), Maintenance Supervisor, or the Operating Manager of the Facility.

### 11.6.2.3 Removal of Obsolete Equipment

When work is to be done to remove old or obsolete equipment, the electrical wiring, conduit, and control boxes must be removed all the way to the source of feed. After the equipment has been removed, the electrical wiring diagrams, schematics, etc., must be updated to show the changes.

### 11.6.2.4 Standby Electrical Power

Selected facilities are supplied with standby electrical service such as generator that automatically takes on selected loads in an event of a primary power failure. These units shall be tested regularly by the Ames Plant Engineering Branch.

### 11.6.2.5 Contractor Connecting into Government Electrical Utilities

Specifications for electrical work that requires interruption of electrical service to a facility must include a clause that requires contractor to notify the Ames Contracting Officer prior to making connection(s) into any part of the Ames Research Center's electrical power distribution system. The application shall state the date, time, location, service involved, and when the connection is to be made. Approval must be obtained before the circuit is de-energized.

### 11.6.2.6 Initial Energizing of Electrical Installation Above 600 Volts

The Engineer or the Technical Monitor is responsible to assure the following safety tests are performed prior to energizing electrical installations for the first time or after a major repair or overhaul for the voltage above 600 V.

- All power circuit breakers, other than sealed molded case, must be checked for proper operation in the trip ranges required. The contacts must be inspected and all adjustments reviewed to ensure proper contact on all units in accordance with the manufacturer's instruction.
- All protective relays and other devices must be tested to ensure their capability of operating in the range required. Tests must include, where possible, secondary current injection at the current transformer secondary side to verify protective circuit operation and relay function.
- All wiring must be checked for conformity to the design drawings and fabrication and functional requirements.

- High-voltage verification tests must be taken of motors, cables, and switchgear to determine their capability of successfully withstanding voltages up to the maximums listed in High Voltage Verification Test Condition section of this chapter.
- Initial energizing of all new electrical equipment will be done only in the presence of an authorized Government representative. The energization plan must be submitted and approved by the cognizant engineer.

#### 11.6.2.7 Protective Relay Settings

- Before energizing any load, protective relays or overloads monitoring the equipment must be set at values established by the Ames Facilities Engineering Branch.
- The Ames Facilities Engineering Branch must maintain a document of all protective relay settings to record the desired up-to-date proper settings.
- The Ames Facilities Engineering Branch is responsible for assuring that protective relay systems are coordinated to provide selective tripping in accordance with best practice on the Ames system.

#### 11.6.2.8 Circuit Interruption Devices

- All circuit interruption devices must be rated to interrupt the maximum short circuit current of the power system at the point of application of the device.
- Whenever large loads or major system changes are made on the power system, short-circuit system studies must be made by the Ames Facilities Engineering Branch to assure maintenance of proper short-circuit interrupting capability.
- In systems above 600 V, after any circuit breaker operation occurs in which the circuit breaker opens under short-circuit conditions or fault, prior to reset, the circuit breaker must be inspected and checked to ensure that the circuit breaker is suitable for reuse in the circuit.
- A preventative maintenance (PM) program must cover all high voltage circuit breakers. The responsibility for defining and implementing the PM will be as defined in the Ames Facilities Engineering Branch Areas of Responsibility document.

### 11.6.3 Contractor Substation Projects

- The Contractor must conform to all the applicable Ames Safety Rules and Regulations.
- The Contractor must submit a work plan 14 days prior to initiating work in the Ames substations. The plan shall outline the work to be done and identify the circuits required to be de-energized to safely conduct the operation. The initial work plan and all changes to this work plan must be reviewed and approved by the responsible Ames personnel prior to initiation.
- The Contractor must appoint an individual responsible for the electrical safety of each work team.
- The Contractor shall restrict entry to the substation to those authorized jointly with Ames.

### 11.6.4 Substation Access

Each organization responsible for working on electrical systems in substations shall establish and implement written policies and procedures for access. The following is the standard access procedures for substations that Ames Plant Engineering Branch is solely responsible for. Organizations shall develop their own written procedures for controlling access to the substations.

### 11.6.4.1 Standard Substation Access Procedures

All personnel, when working in Plant Engineering's controlled high voltage substations will abide by the following procedures for the circumstance indicated.

Prior to entering any substation Ames Plant Engineering Branch must be notified. Call the Ames High Voltage Shop at extension **REDACTED** and inform the high voltage supervisor of what substations you will be in and when you will be in it. Notification should be made 24 hours in advance if possible. If it is not possible to give 24-hour notice, then call the above number. If the supervisor is not available leave a message and try at least once to raise him with the radio on the maintenance management channel.

If other personnel are present in the substation when you are visiting, inform them where in the substation you will be. If they are still present when you leave let them know that you are leaving.

#### 11.6.4.1.1 General

- At least two people shall be involved in all entries into the substations to perform work in the substations.
- The entry gate will be closed but unlocked while the person is working in the substation.
- The entry gate will be locked on exit from the substation.

#### 11.6.4.1.2 Substation Data Gathering

Nameplate Data Gathering

- Unlocked control cabinets with handles can be opened to obtain data. Any panel that requires unbolting or panel disassembly to enter requires the assistance of an Ames Electrician.
- No switching, wiring or measurements will be made on any low or high voltage circuits.

Low Voltage Circuit Data Gathering (At or Below 600 V)

- Circuit data to be gathered can consist of voltage, ampacity, watts, vars, power factor and harmonics. No circuits will be opened.
- Review Low Voltage Circuit Data Gathering Plan with Ames Electrician. Determine if assistance is required.
- No switching, wiring or circuit alterations will be made on any low or high voltage circuits.

Circuit Data Gathering That Requires Switching and/or Circuit Modifications

- At least one of the two required people will be an Ames high voltage electrician.
- Ames Facilities Engineering Branch in conjunction with the Ames Plant Engineering Branch high voltage electricians will develop a plan for the switching and/or circuit modifications that will be necessary.
- All switching and/or circuit modifications that impact operations of any facilities will be cleared through the Ames Plant Engineering and Ames Facilities Engineering Branch.
- A tailgate meeting will be held prior to the switching and/or circuit modifications to review the plan and the safety procedures.
- The Ames Plant Engineering Branch high voltage electricians will perform all switching and/or circuit modifications.

### 11.6.5 Temporary Electrical Installation

- Low voltage (at or below 600 V) open wiring shall be guarded or elevated 10 feet above walkway to prevent accidental contact by workers who may be carrying construction materials or tools.
- Use portable power tools that have identified grounding conductors connected to the frames or are double insulated with a UL label.
- Use cords that are connected to the grounding contact of an approved plug and UL-listed for the intended use.
- Use an appropriately sized ground fault circuit interrupter (GFCI) near the power source on temporary circuits that power tools.

## 11.7 Special Equipment Handling Procedures

### 11.7.1 Batteries

- Enclosed areas containing storage batteries shall be adequately ventilated.
- Smoking, open flames, and tools, which may produce sparks, are prohibited in enclosed battery storage areas.
- Workers shall not handle energized parts of batteries unless necessary precautions are taken to avoid shock and short circuits.
- When handling vented cells, batteries, caustic electrolyte or acid electrolyte, always wear safety goggles, rubber gloves, and a protective rubber apron. Refer to APG 1700.1, Chapter 33 for further information regarding selection, use and maintenance of PPE. If electrolyte gets into eyes, flush with water for 15 minutes while someone dials 9-1-1 for emergency assistance.
- Adjust the electrolyte in each cell in accordance with the manufacturer's procedures.
- Use a voltage limited current taper charging method is recommended to reduce off-gassing and potential electrolyte spewing.
- Provide an easily removable cover for the battery containers.
- Ensure battery cells have vented covers that will minimize pressure build up.
- Do not seal vented cells in a container that will trap gasses.

### 11.7.2 Fuses

When removing or replacing fuses, the following safety requirements apply:

| Voltage | Requirements |
|---|---|
| 50 to 599 V | Use low voltage gloves and fuse tongs or insulated fuse |
| Above 600 V | Use Class 2 gloves and high voltage sticks or tongs |
| Above 2,300 V (overhead lines) | Use Class 2 gloves and high voltage sticks or tongs |
| Above 2,300 V (non-overhead lines) | Fuse shall not be removed or replaced until the circuits or equipment is de-energized, tagged, grounded, and tested for voltage. |

1. Capacitor Banks (High Voltage)all V are employed, ensure that test personnel conducting maintenance, repair, or inspections have total knowledge of the energy storage system including, control circuit and component layout. The test personnel shall be fully trained

in the operating and safety procedures to be used, including procedures to be used in the event of equipment malfunction or failure.

2. Capacitors and related high voltage component faults are a source of hazardous shrapnel and flying debris. Isolation of these components shall be provided to prevent personnel injury or facility related hazards such as fire. Isolation shall be provided through either system enclosure or controlled access through the use of gates and interlocks, which are integrated into the system controls.
3. High voltage warning signs shall be conspicuous, and a warning system shall be used to indicate that tests are in progress.
4. The controls or mechanisms shall provide a system which indicates the position of a shorting switch grounding device that discharges the capacitor bank. This device should be fail-safe and function to a safe configuration with no electrical power.
5. A voltmeter connected across the capacitor bank should be clearly visible to the test operator at all times. A redundant voltmeter should be installed at the capacitor banks.
6. Prior to touching a high voltage component within the test area, a hot stick of appropriate design shall be used to ensure that the capacitor bank is fully discharged to the building ground.
7. Use extreme caution on capacitor banks that are operated by DC voltages. A DC capacitor bank will maintain a residual voltage for extended periods. Therefore, the capacitor bank must be grounded when it is not in a charge mode.
8. Capacitors that are connected in series as a bank should be treated with caution. Each and every terminal in a series should be shorted to ground prior to making any changes or performing maintenance on the capacitor bank or control circuit.

## 11.8 Hazards Of Electricity

### 11.8.1 Hazards of Electric Arc/Blast

**Electrical Arc**

Electrical arcs produce temperatures up to 35,000°F. At these temperatures, fatalities can occur at distances greater than 10 ft from the arc and light first degree burns at distances up to 40 ft from the arc. The temperature effect on human skin is determined by the power of the arc (system voltage x short circuit current) and the distance from the arc.

**Electrical Blast**

Electrical blast is produced by the rapid expansion of the air in an arcing situation. When an arc develops metals are melted and in most cases vaporized. This vaporization of metals, mainly copper, produces an expansion of the air around the arc. When copper vaporizes it expands to 67,000 times its original volume. In comparison, water turning to steam expands 1670 times. If 1 cubic inch of copper is vaporized it produces 1.44 cubic yards of vapor. This is the same expansion that is produced with dynamite when it explodes..

There are three types of burns as result of electric arc and blast:

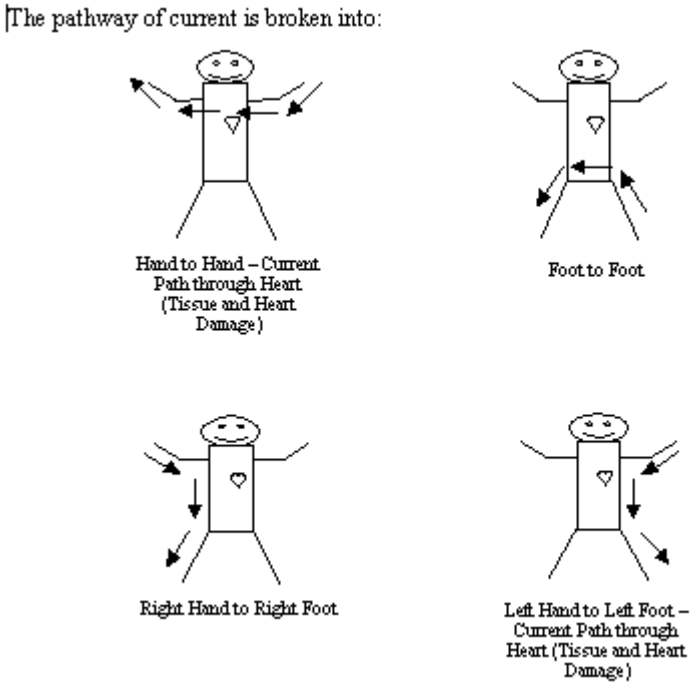
| | |
|---|---|
| First Degree | Effects the surface of the skin, burn areas will be red and tender |
| Second Degree | Blistering of the skin, very painful. |
| Third Degree | Complete destruction of the skin, cooking of the deeper tissues, permanent damage and disfigurement. |

### 11.8.2 Hazards of Electric Shocks

Electric shocks are the result of a living organism coming in contact with and becoming part of an electric circuit.

Persons who handle electrical equipment mistakenly believe their tolerance of electric shock is related to their ability to withstand pain of the shock.

Actually, the lethal incidence is a function of current passage (duration and level) through the heart region. Often a shock victim is spared because the current path does not pass through a vital organ. For example, a right hand-foot path is less likely to result in fibrillation than a left hand-foot path because there is no path through the heart.




There are two types of Electric Shocks:

- Macro-Shock---From outer skin
- Micro-Shock---Electrode penetration through outer skin

Most industrial electrocutions are due to macro-shock where the outer epidermis is intact.

**The killer in an electric shock is the current.**

#### 11.8.2.1 Body Current Levels at 110 Volts AC

Typical body current paths are listed in table below. It is obvious that severe injury can happen if extreme care is not taken when working with electrical equipment.

| Path | Current |
|---|---|
| Dry Skin | Less than 1 mA |
| Wet Skin | 110 mA |
| Ear to Ear | 1.1 A |
| Hand to Foot | 220 mA |

### 11.8.2.2 Effects of Electric Shocks

| Alternating Current | Physiological Phenomena | Feeling or Lethal Incidence |
|---|---|---|
| 1 mA | Perception threshold | Mild sensation, tingling |
| 10 mA * | Paralysis threshold of arms | "Let Go", muscle contraction, cannot release handgrip. |
| 50 mA | Pain | Fainting, exhaustion, mechanical injury. Heart and respiratory function intact. |
| 0.1 to 2-3 A | Heart paralysis threshold | Ventricular fibrillation. Respiratory center intact. |
| 6.0 to 30 A | Heart paralysis | Sustained myocardial contraction followed by normal rhythm. |
| Above 30 A | Tissue Burning | Body burns or cooks. |

*At 5 mA--A circuit protected by a Ground Fault Circuit Interrupter will trip (open the energized circuit) when the GFCI detects a 5 mA difference between the hot and the neutral.

### 11.8.2.3 Summary

As shock current values increase they are statistically more dangerous from burn-type damage than heart failure. This is most likely due to the shorter exposure times. When voltages above 2,300 V are involved, burns may not be severe as the victim initiates an arc that retracts (by reflex) his attempted grip. In summary, humans are affected in major proportion by the duration as well as the level of shock. When contact is made in such a manner as to retract the contacting part (such as a light finger touch when the strong muscular contractions of the arm pull the fingers away), the shock is much less dangerous than one of the same current level incurred by "freezing" to the contact with a full hand grasp.

# 11.9 Appendices

## 11.9.1 Appendix 11-A: Ames Designated Wiring Devices

1. NEMA standard devices of the grounding type must be used where applicable (see pages 11-A-3 and 11-A-4).
2. Phase rotation of all NEMA standard devices must be C-B-A, or 3-2-1, or clockwise rotation of the Ames rotation meter when connected X to black, Y to red, and Z to blue.
3. Special devices where no NEMA standard exists (see Page 11-A-5).

   a. For 208 volt, three-phase circuits

| | | | |
|---|---|---|---|
| 1 | 50 A | Receptacle, Hubbell No. 7379, Or Equal | (Fig. 1) |
| 2 | 50 A | Cap, Hubbell No. 7765, Or Equal | (Fig. 1) |
| 3 | 50 A | Connector Body, Hubbell No. 7764, Or Equal | (Fig. 1) |
| 4 | 50 A | Male Motor Base, Hubbell No. 7968, Or Equal | (Fig. 1) |
| 5 | 60 A | Receptacle, Hubbell No. 26520, Or Equal | (Fig. 2) |
| 6 | 60 A | Cap, Hubbell No. 26519, Or Equal | (Fig. 2) |
| 7 | 60 A | Female Cord End, Hubbell No. 26516, Or Equal | (Fig. 2) |
| 8 | 100 A | Receptacle, Crouse Hinds No. AR 1041 | (Fig. 3) |
| 9 | 100 A | Male Cord End, Crouse Hinds APJ 10477 | (Fig. 3) |
| 10 | 100 A | Female Cord End, Crouse Hinds APR 10457 | (Fig. 3) |
| 11 | 200 A | Receptacle, Crouse Hinds No. AR 2042 | (Fig. 4) |
| 12 | 200 A | Male Cord End, Crouse Hinds No. AP 20468 | (Fig. 4) |
| 13 | 200 A | Female Cord End, Crouse Hinds No. ARP 20428 | (Fig. 4) |

   b. For 460 volt, three-phase circuits

| | | | |
|---|---|---|---|
| 1 | 60 A | Receptacle, Crouse Hinds No. AR 642 | (Fig. 5) |
| 2 | 60 A | Male Cord End, Crouse Hinds No. APJ 6467 | (Fig. 5) |
| 3 | 60 A | Female Cord End, Crouse Hinds No. ARO 6455 | (Fig. 5) |
| 4 | 100 A | Receptacle, Crouse Hinds No. AR 1042 | (Fig. 6) |
| 5 | 100 A | Male Cord End, Crouse Hinds No. APJ 10487 | (Fig. 6) |
| 6 | 100 A | Female Cord End, Crouse Hinds No. APR 10467 | (Fig. 6) |
| 7 | 200 A | Receptacle, Crouse Hinds No. AR 2031 | (Fig. 7) |
| 8 | 200 A | Male Cord End, Crouse Hinds No. AP 20357 | (Fig. 7) |
| 9 | 200 A | Female Cord End, Crouse Hinds No. APR 20317 | (Fig. 7) |

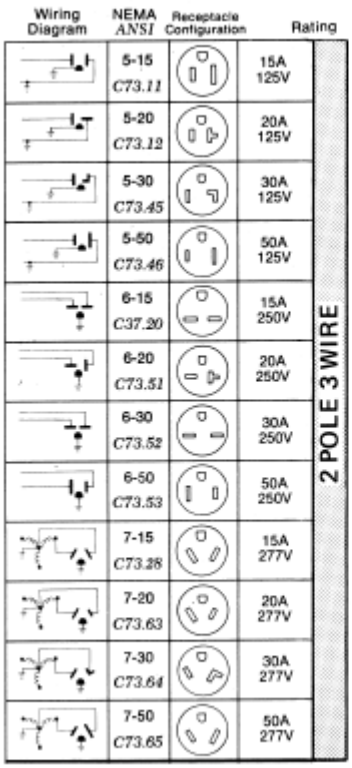
4. The special devices must be connected and phased for clockwise rotation as shown in the sketches following.

## Locking Type Wiring Devices - Grounded - NEMA Configurations

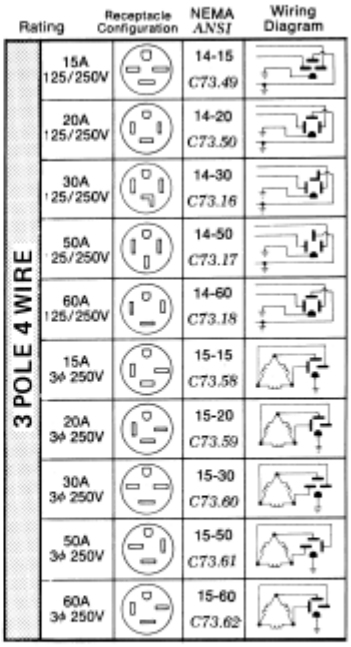
| Wiring Diagram | NEMA ANSI | Receptacle Configuration | Rating | |
|---|---|---|---|---|
| | ML2 C73.44 | | 15A 125V | 2 POLE 3 WIRE |
| | L5-15 C73.42 | | 15A 125V | |
| | L5-20 C73.72 | | 20A 125V | |
| | L5-30 C73.73 | | 30A 125V | |
| | L6-15 C73.74 | | 15A 250V | |
| | L6-20 C73.75 | | 20A 250V | |
| | L6-30 C73.76 | | 30A 250V | |
| | L7-15 C73.43 | | 15A 277V | |
| | L7-20 C73.77 | | 20A 277V | |
| | L7-30 C73.78 | | 30A 277V | |
| | L8-20 C73.79 | | 20A 480V | |
| | L8-30 C73.80 | | 30A 480V | |
| | L9-20 C73.81 | | 20A 600V | |
| | L9-30 C73.82 | | 30A 600V | |

| Rating | Receptacle Configuration | NEMA ANSI | Wiring Diagram | |
|---|---|---|---|---|
| 20A 125/250V | | L14-20 C73.83 | | 3 POLE 4 WIRE |
| 30A 125/250V | | L14-30 C73.84 | | |
| 20A 3∅ 250V | | L15-20 C73.85 | | |
| 30A 3∅ 250V | | L15-30 C73.86 | | |
| 20A 3∅ 480V | | L16-20 C73.87 | | |
| 30A 3∅ 480V | | L16-30 C73.88 | | |
| 30A 3∅ 600V | | L17-30 C73.89 | | |
| 20A 3∅Y 120/208V | | L21-20 C73.90 | | 4 POLE 5 WIRE |
| 30A 3∅Y 120/208V | | L21-30 C73.91 | | |
| 20A 3∅Y 277/480V | | L22-20 C73.92 | | |
| 30A 3∅Y 277/480V | | L22-30 C73.93 | | |
| 20A 3∅Y 347/600V | | L23-20 C73.94 | | |
| 30A 3∅Y 347/600V | | L23-30 C73.95 | | |

## Straight Blade Wiring Devices– Grounded– NEMA Configurations



| Wiring Diagram | NEMA ANSI | Receptacle Configuration | Rating | |
|---|---|---|---|---|
| | 5-15 C73.11 | | 15A 125V | 2 POLE 3 WIRE |
| | 5-20 C73.12 | | 20A 125V | |
| | 5-30 C73.45 | | 30A 125V | |
| | 5-50 C73.46 | | 50A 125V | |
| | 6-15 C37.20 | | 15A 250V | |
| | 6-20 C73.51 | | 20A 250V | |
| | 6-30 C73.52 | | 30A 250V | |
| | 6-50 C73.53 | | 50A 250V | |
| | 7-15 C73.38 | | 15A 277V | |
| | 7-20 C73.63 | | 20A 277V | |
| | 7-30 C73.64 | | 30A 277V | |
| | 7-50 C73.65 | | 50A 277V | |



| Rating | Receptacle Configuration | NEMA ANSI | Wiring Diagram | |
|---|---|---|---|---|
| 15A 125/250V | | 14-15 C73.49 | | 3 POLE 4 WIRE |
| 20A 125/250V | | 14-20 C73.50 | | |
| 30A 125/250V | | 14-30 C73.16 | | |
| 50A 25/250V | | 14-50 C73.17 | | |
| 60A 125/250V | | 14-60 C73.18 | | |
| 15A 3Φ 250V | | 15-15 C73.58 | | |
| 20A 3Φ 250V | | 15-20 C73.59 | | |
| 30A 3Φ 250V | | 15-30 C73.60 | | |
| 50A 3Φ 250V | | 15-50 C73.61 | | |
| 60A 3Φ 250V | | 15-60 C73.62 | | |

## Phasing– Ames Special Devices - All Front View of Receptacles

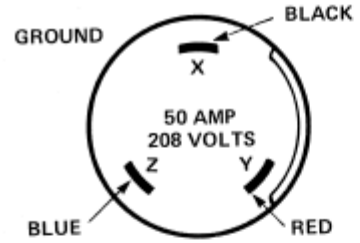


FIG. 1

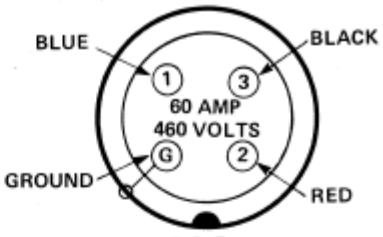


FIG. 5

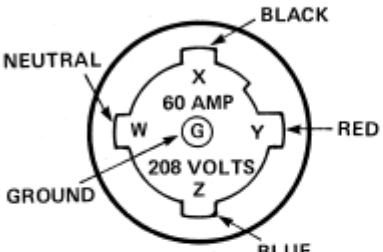


FIG. 2

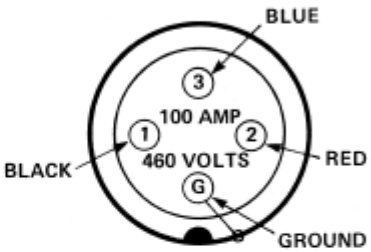


FIG. 6

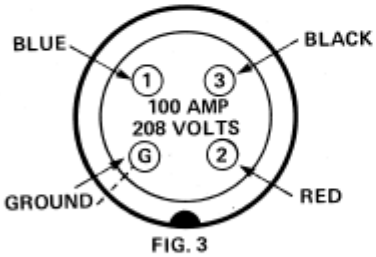


FIG. 3

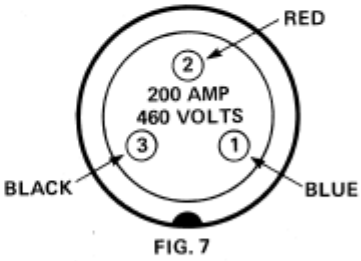


FIG. 7

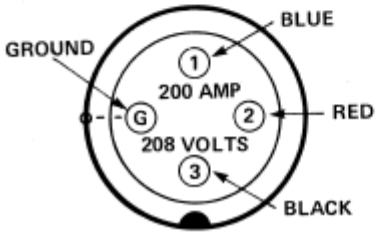


FIG. 4

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