Industrial Maintenance

Electrical Wiring

Courseware Sample

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Safety and Common Symbols

The following safety and common symbols may be used in this manual and on the equipment:

Symbol	Description
⚠ DANGER	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
⚠ WARNING	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
⚠ CAUTION	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger* sign ⚠, indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger
	Caution, lifting hazard
	Caution, hand entanglement hazard
	Notice, non-ionizing radiation
	Direct current
	Alternating current
	Both direct and alternating current
	Three-phase alternating current

Safety and Common Symbols

Symbol	Description
	Earth (ground) terminal
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

We invite readers of this manual to send us their tips, feedback, and suggestions for improving the book.

Please send these to did@de.festo.com.

The authors and Festo Didactic look forward to your comments.

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Preface

The Industrial Wiring Training System, Model 46102, faithfully reproduces an industrial environment where students can develop their skills in the installation and wiring of industrial electrical equipment, in compliance with the National Electrical Code® (NEC®). The system can also be used to teach how to adjust and maintain industrial electrical equipment as well as enforce the safety rules to be followed when working at industrial sites.

Due to its modular design, the Industrial Wiring Training System can be configured to fit various training needs. A versatile, mobile workstation is the basis of the system. The following equipment packages, tool packages, and industrial application packages are available to adjust the curriculum to various training levels:

- Enclosures and Conduits
- Electrical Power Distribution
- Three-Phase Power Bus
- Electrical Wiring
- Electrical Wiring Tools
- Three-Phase Motor with Forward Starter and Soft Starter
- AC Motor Drive with Inverter Duty Motor
- PWM DC Motor Drive with Permanent Magnet DC Motor
- Inertia Load Application
- Blower Application
- Power Quality Analyzer

All of the above packages consist of industrial-type equipment and tools for realistic training.

We hope that your learning experience with the Industrial Wiring Training System will be the first step of a successful career as an electrician.

We invite readers of this manual to send us their tips, feedback, and suggestions for improving the book.

Please send these to did@de.festo.com.

The authors and Festo Didactic look forward to your comments.

About This Manual

The job sheets in this manual provide a systematic and realistic means of learning how to install and wire electrical equipment in accordance with the National Electrical Code® (NEC®). When you have completed these job sheets, you will have built a complete overhead door simulator operating in the same way as actual overhead door systems.

Safety considerations

Safety symbols that may be used in this manual and on the equipment are listed in the Safety Symbols table at the beginning of the manual.

Safety procedures related to the tasks that you will be asked to perform are indicated in each exercise.

Make sure that you are wearing appropriate protective equipment when performing the tasks. You should never perform a task if you have any reason to think that a manipulation could be dangerous for you or your teammates.

It is recommended to complete the safety checklist in Appendix C of this manual at the beginning of any job sheet.

Reference material

Before performing the job sheets in this manual, you should browse references 1 to 5 given in Appendix E. These references introduce you to the information and theory necessary to perform the job sheets. You can also refer to the articles of the National Electrical Code® (NEC®) that are mentioned in these references.

Appendices

Appendix A, *Equipment Utilization Chart*, indicates the components, specialized tools, and consumable goods (flexible metal conduit, liquidtight flexible nonmetallic conduit, conductors, etc.) that are required to complete each of the job sheets in this manual. The chart also provides the part number of each component, specialized tool, and consumable good.

Appendix B, *Basic Tools Required*, lists the basic tools that are recommended to perform the job sheets in this manual. These tools should normally be provided by the student.

Appendix C, *Basic Safety Procedures*, lists the basic safety procedures to be performed before you begin any of the job sheets in this manual.

Appendix D, *Lockout/Tagout Procedure*, provides the lockout/tagout procedure specific to the Industrial Wiring Training System.

Appendix E, *Reference Material*, lists references to sections and modules of the Electrical Trainee Guides from the National Center for Construction, Education, and Research (NCCER). These references provide the information and theory necessary to perform the job sheets in this manual.

About This Manual

Photographs in the Job Sheets

Photographs in the job sheets show several electrical components used in the overhead door simulator as well as the construction of the overhead door simulator at various stages. Most of these photographs were taken at the time the overhead door simulator was designed. Although every effort is made to keep these pictures up-to-date, you may notice some differences between what is shown in the pictures and the components you received. This is normal and reflects our commitment towards continuous product improvement.

Systems of units

Units are expressed using the U.S. customary system of units followed by the units expressed in the International System of Units (SI) (between parentheses).

To the Instructor

You will find in this Instructor Guide all the elements included in the Student Manual together with the answers to all questions, results of measurements, graphs, explanations, suggestions, and, in some cases, instructions to help you guide the students through their learning process. All the information that applies to you is placed between markers and appears in red.

Accuracy of measurements

The numerical results of the hands-on exercises may differ from one student to another. For this reason, the results and answers given in this manual should be considered as a guide. Students who correctly performed the exercises should expect to demonstrate the principles involved and make observations and measurements similar to those given as answers.

Instructions

- Before a student begins a job sheet, make sure that the equipment is in good condition and does not represent any risk when used.
- When a student has to complete a setup that is partially mounted, ensure that the setup corresponds to the task requested in the job sheet.
- Whenever a lockout/tagout is required, make sure that each student working on the Industrial Wiring Training System has and installs a padlock on the safety switch handle of the system's three-phase power bus.
- Before a student begins a job sheet, make sure that he or she has read the relevant sections of the reference material and understands the objectives of the job to be done.
- For each job sheet, this guide provides you with the list of points that should be checked to assess the student's work. The guide also provides notes that contain complementary information on the way of performing certain job sheets.
- Photographs in the job sheets show several electrical components used in the overhead door simulator as well as the construction of the overhead door simulator at various stages. Most of these photographs were taken at the time the overhead door simulator was designed. Although every effort is made to keep these pictures up to date, you may notice some differences between what is shown in the pictures and the components you received. This is normal and reflects our commitment toward continuous product improvement.

Sample Job Sheet

Extracted from

Electrical Wiring

Wiring of the Motor Control Circuit

OBJECTIVE

To install the electrical components of the motor control circuit on the mounting plate of the motor control enclosure. To wire these components according to the connection diagram of the motor control circuit and in compliance with the National Electrical Code® (NEC®).

PROCEDURE

1. Note that the electrical components of this job sheet must be wired in compliance with Articles 110, 250, 310, 312, and 430 of the NEC®. You should read and understand these articles.

2. Identify the fused, three-pole safety switch. Figure 23 shows an example of this type of safety switch. Notice that the switch shown in Figure 23 is provided with removable fuse holders.

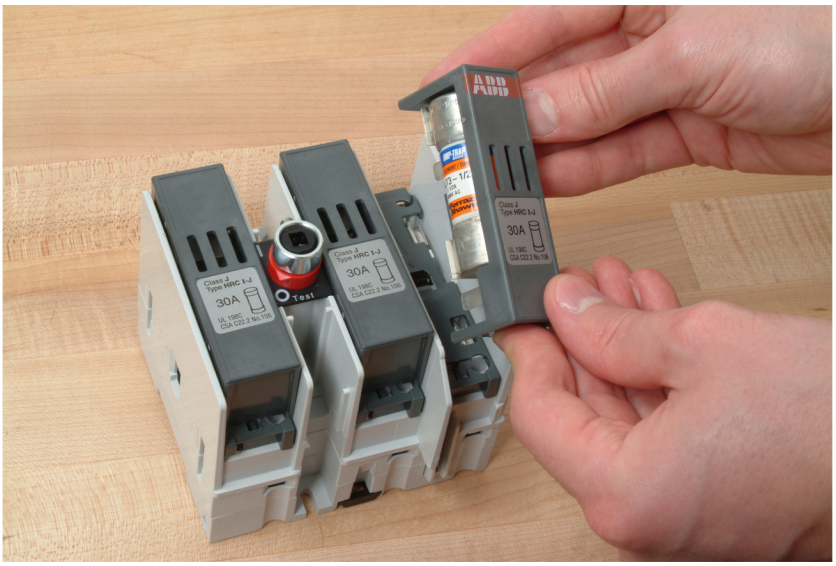

Figure 23. A three-pole safety switch.

The three fuses installed in this safety switch are called dual-element time-delay fuses. The expression "time-delay" means the fuse allows for the current to be drawn to peak up high for a brief moment. For instance, when the door motor starts, the current needed to start the motor peaks up for a few seconds without melting the fuse. For more information on fuses, read reference 6 (see Appendix E).

The description and part number of each electrical component described in this job sheet are provided in the Equipment Utilization Chart (Appendix A of this manual).

3. Identify the two three-pole contactors. They consist of two three-pole contactors, a mechanical interlocking device, and two auxiliary contact units, as shown in Figure 24.

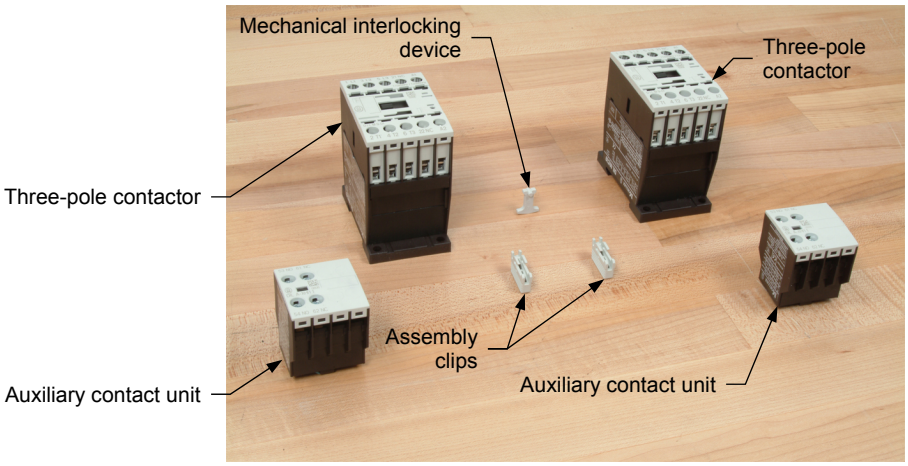

Figure 24. Typical components required to assemble a dual three-pole contactor unit.

A contactor is an electrically controlled switch used for switching a power circuit. A contactor is activated by a control input which is at a lower voltage than that which the contactor is switching.

A three-pole contactor is easily identified by its main contact terminals which are labeled L1, L2, L3 and T1, T2, T3, as well as its power rating which is expressed in both kilowatts (kW) and horsepower (hp).

An auxiliary contact unit is a small device designed to be attached to a contactor. It has no coil (no terminals labeled A1 and A2) and is actuated by the contactor.

For more information on contactors, read reference 7 (see Appendix E).

4. Assemble the two three-pole contactors, the mechanical interlocking device, and the two auxiliary contact units as indicated in the diagram of Figure 25. Verify that the mechanical interlock is operational.

To test it, try to actuate the two contactors at the same time using two pen or flat head screwdrivers. You should not be able to actuate the two contactors at the same time.

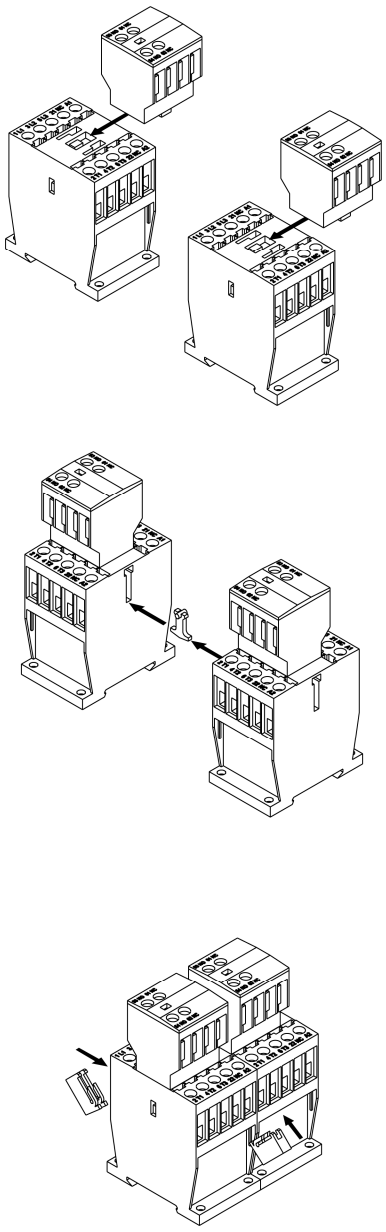

Figure 25. Dual three-pole contactor assembly diagram.

5. Identify the fuse-protected, control voltage transformer. A fuse-protected, control voltage transformer is shown in Figure 26. This kind of transformer is easily recognizable by the fuse holder attached to the unit.

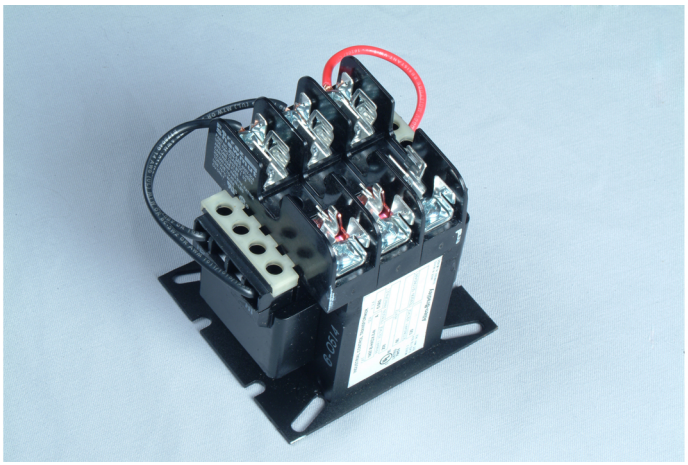

Figure 26. A fuse-protected, control voltage transformer.

A control voltage transformer is used to supply power to the control circuit by reducing the voltage from the power circuit to a voltage suitable for the control circuit. It is connected to two of the three phases of the power supply. For more information on control transformers, read reference 8 (see Appendix E).

6. Identify the overload and the control relays. An example of each component is shown in Figure 27.

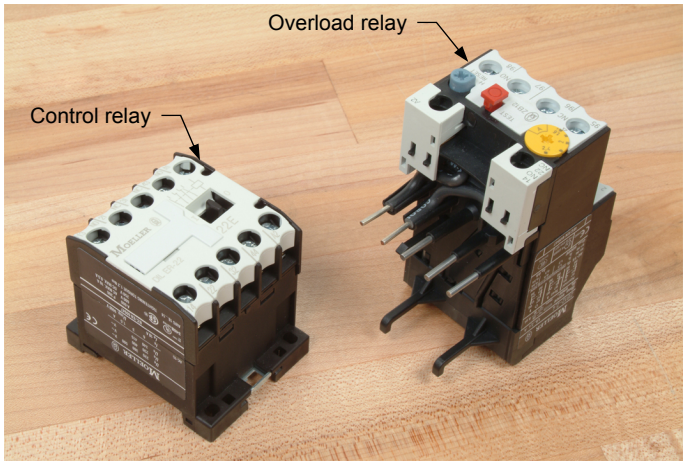

Figure 27. An overload relay and a control relay.

An overload relay is recognized by its current setting knob and reset button. Many also have a test button. Overload relays are used to interrupt the power if an overload is detected. For more information on overload relays, read reference 9 (see Appendix E).

A control relay is identified by its coil terminals which are usually labeled A1 and A2, as well as its contact terminals which are labeled with numbers (e.g., 13 and 14, 21 and 22, 31 and 32, etc.). Its contacts are usually rated in terms of current at a specific voltage.

A control relay is an electrical switch that opens and closes under the control of another electrical circuit. It is very similar to a contactor. For more information on control relays, read reference 10 (see Appendix E).

7. Identify the various items that are required to assemble a terminal block. Figure 28 shows typical terminal block items as well as an assembled terminal block.

   Terminal blocks are electrical connectors on which wires are clamped down to contacts by screws.

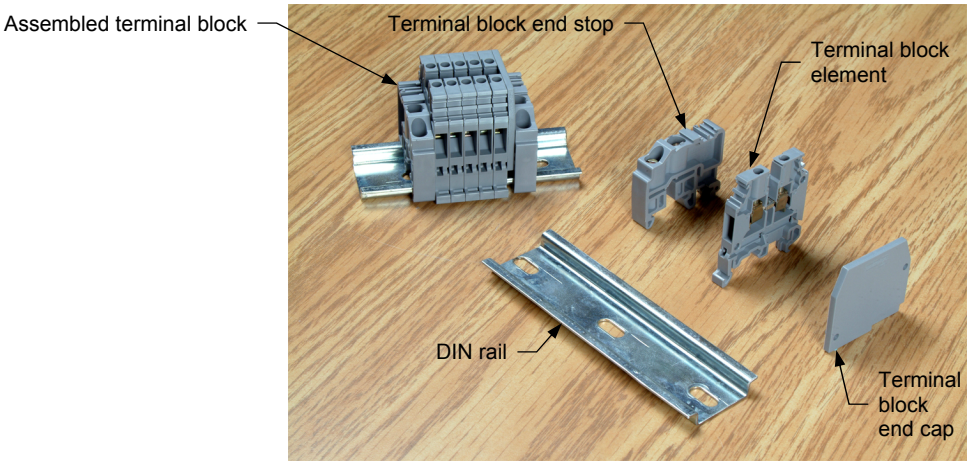

Figure 28. Items required to assemble a terminal block.

8. Remove the mounting plate from the motor control enclosure and place it on a flat surface (e.g., a work bench).

9. Install the fused, three-pole safety switch on the mounting plate of the motor control enclosure (MCE) at the location indicated in the connection diagram of the motor control circuit. To do so:

   - Cut a 6" long piece of DIN rail.
   - Burr and chamfer the sharp edges of the rail.

- Determine the location of the switch so that the axis of the switch's shaft is aligned as closely as possible with the center of the square opening in the MCE door panel as shown in Figure 29.

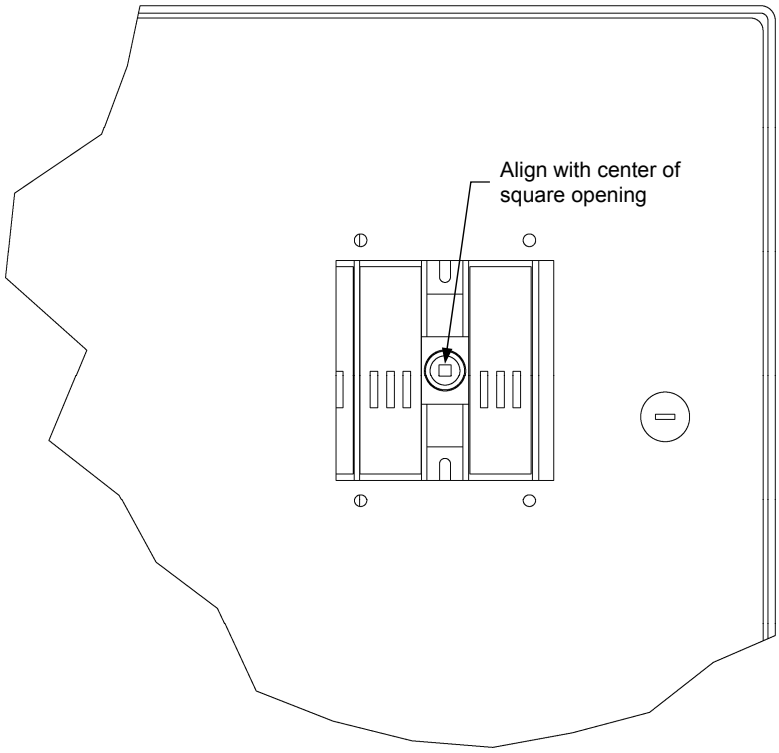

Figure 29. Align the switch's shaft with the center of the square opening in the MCE.

- Determine the location of the holes to be drilled for the DIN rail on the mounting plate.
- Before you drill holes in the mounting plate, ask your instructor to check whether or not the location at which you choose to install the three-pole safety switch is correct.
- Drill the two holes and chamfer their edges.
- Install the DIN rail on the mounting plate using two 3/8", 10-32 screws and two 10-32 kep hex nuts as shown in Figure 30.

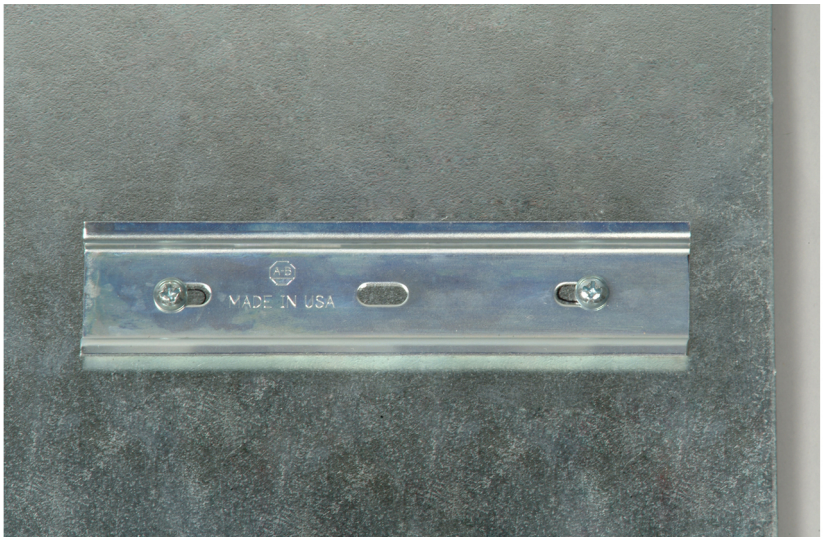

Figure 30. Install the DIN rail on the mounting plate.

- Slide the safety switch on the DIN rail, and center it.
- Slide an end block on each side of the safety switch to secure it to the DIN rail as shown in Figure 31.

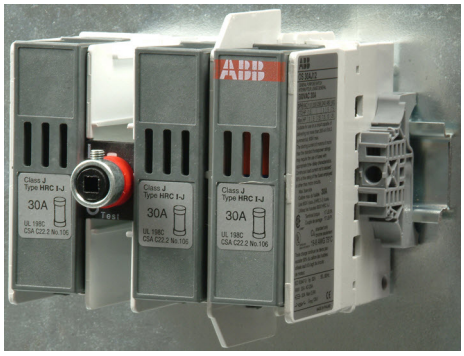

Figure 31. End block used to secure the switch to the DIN rail.

10. Install the overload relay on one of the two three-pole contactors that you assembled earlier in this job sheet. Figure 32 shows how to install an overload relay on a three-pole contactor.

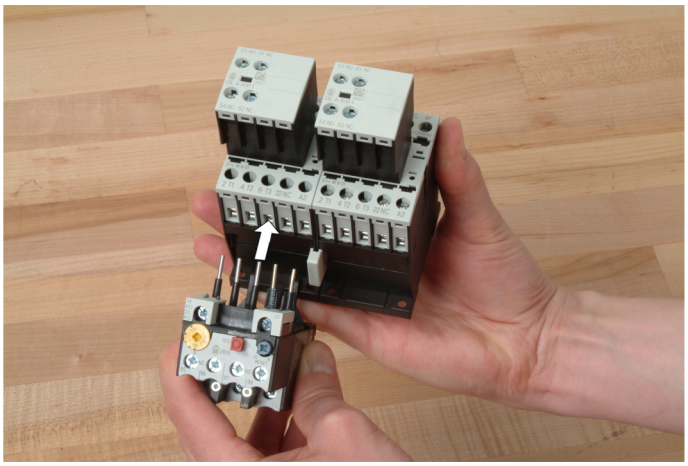

Figure 32. Installing an overload relay on a three-pole contactor.

11. Install the two three-pole contactors and the overload relay on the mounting plate of the motor control enclosure at the location indicated in the connection diagram of the motor control circuit. To do so:

    - Prepare a 12" long piece of DIN rail.
    - Determine the location of the two three-pole contactors and the overload relay on the MCE mounting plate so that the axis of the RESET button on the overload relay is aligned with the center of the circular opening in the MCE door panel as shown in Figure 33.

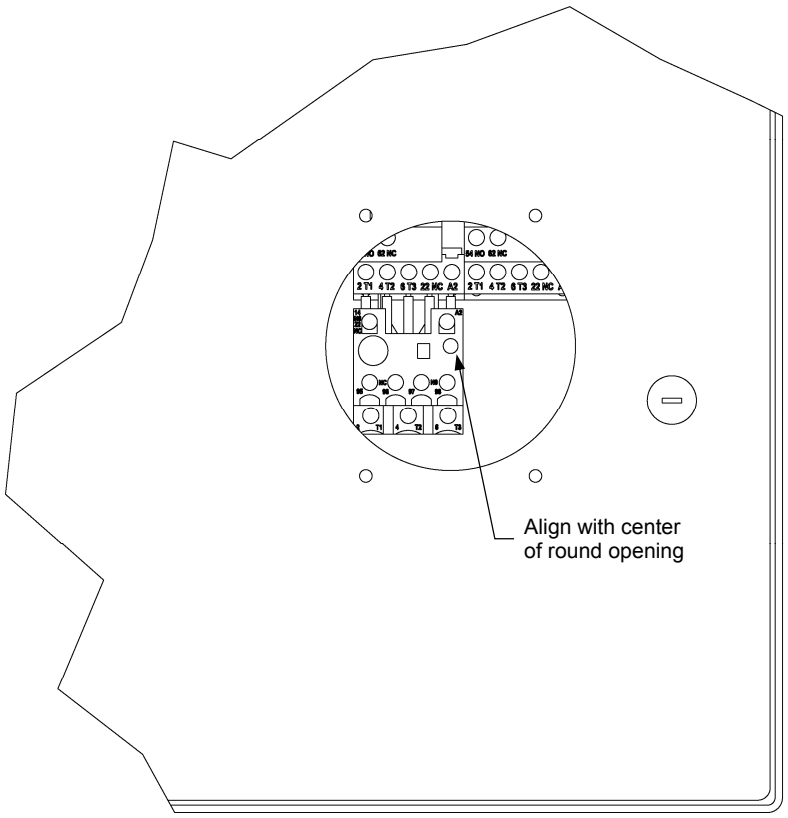

Figure 33. Align the reset button with the center of the round opening in the MCE.

- Before you drill holes in the mounting plate, ask your instructor to check whether or not the location at which you elect to install this component assembly is correct.
- Drill the two holes and mount the DIN rail on the mounting plate.
- Refer to Figure 34 and mount the contactors and overload relay assembly on the DIN rail you just installed.

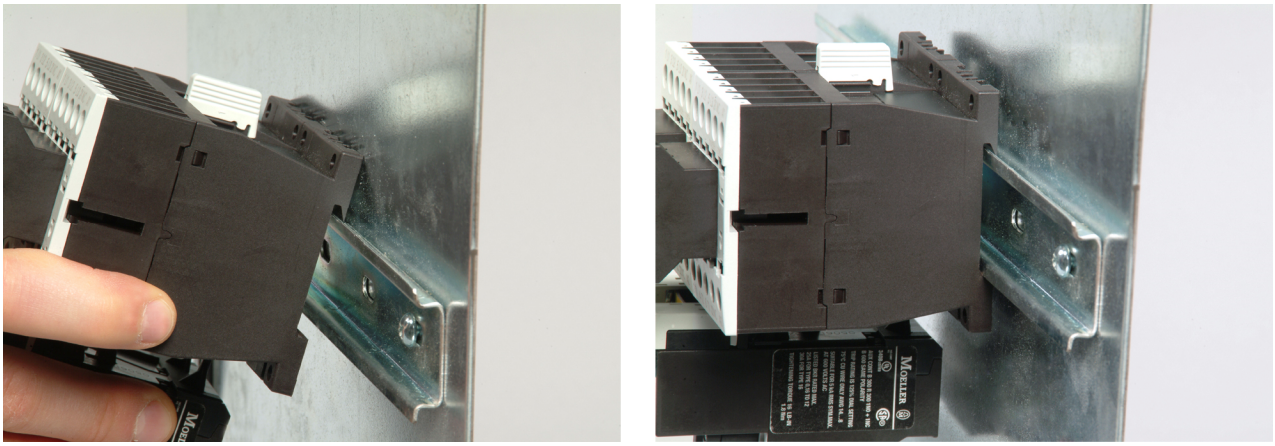

Figure 34. Mount the contactors and overload relay assembly on the DIN rail.

- Verify that all the components shown in Figure 35 are mounted on the mounting plate before continuing with the installation procedure.

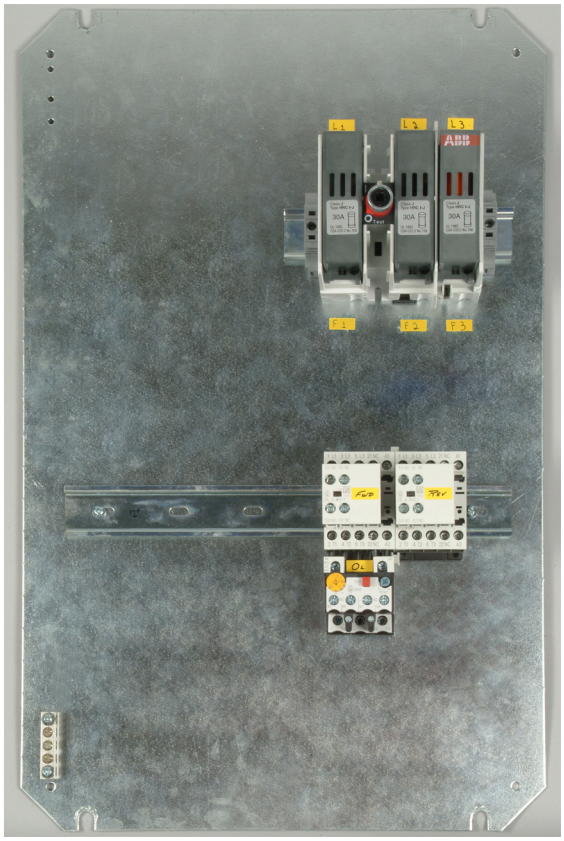

Figure 35. Mounting plate at this stage of the installation procedure.

12. Install the control voltage transformer on the mounting plate of the motor control enclosure as indicated in the connection diagram of the motor control circuit. The transformer is mounted on the mounting plate with screws and kep nuts. A DIN rail is not required.

13. Install the control relay on the mounting plate of the motor control enclosure as indicated in the connection diagram of the motor control circuit. Install it on the same DIN rail on which you installed the contactors and overload relay assembly.

14. Install the terminal blocks on the mounting plate of the motor control enclosures indicated in the connection diagram of the motor control circuit.

- Prepare a 12" long piece of DIN rail.
- Before you drill holes in the mounting plate, ask your instructor to check whether or not the location at which you choose to install this component assembly is correct.

- Drill two holes and mount the DIN rail on the mounting plate.
- Refer to Figure 36 and assemble the two sets of terminal blocks.

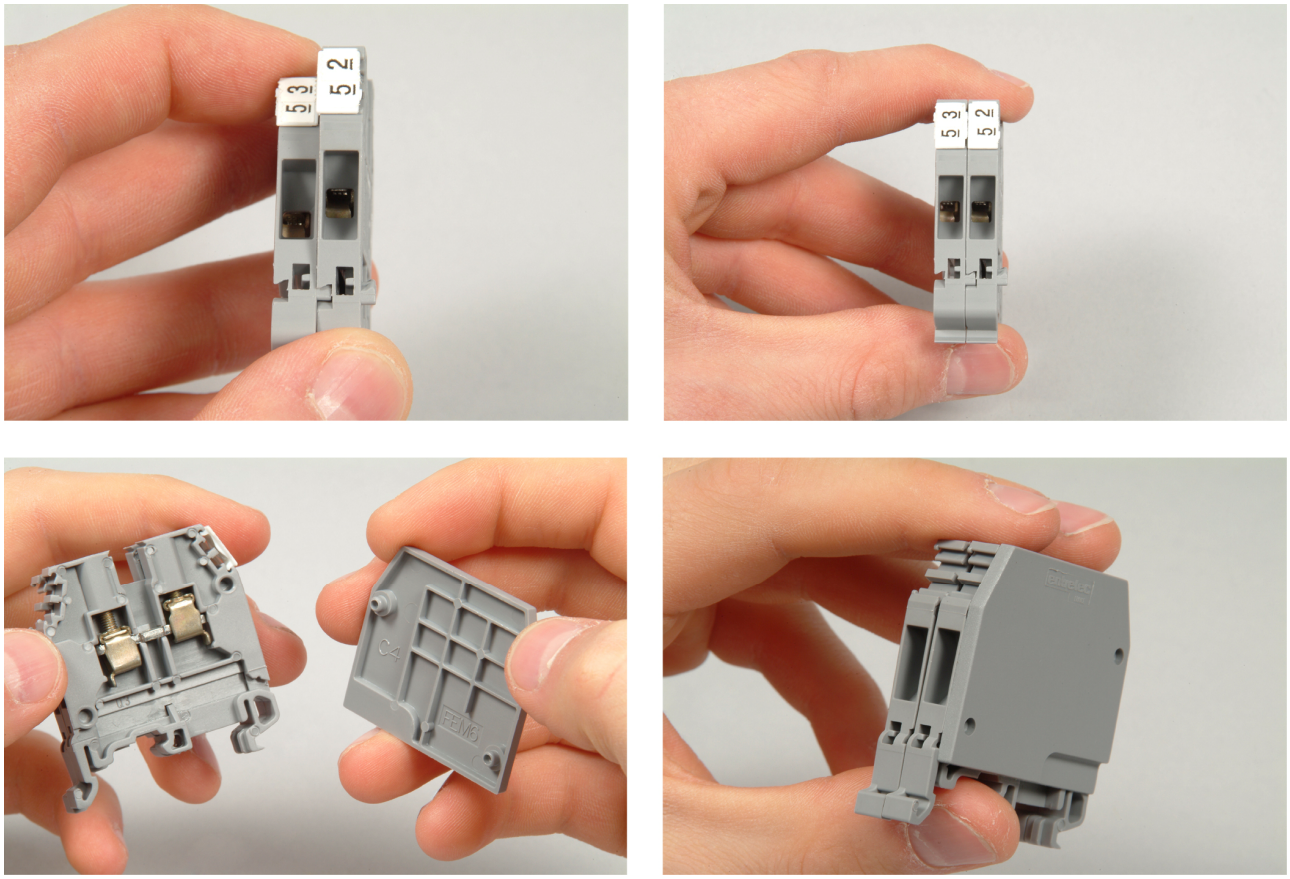

Figure 36. Assembly of terminal blocks.

- Install the assembled terminal blocks on the DIN rail you just prepared. Use two terminal block end stops to secure each set to the DIN rail. Verify that all the components shown in Figure 37 are installed on the mounting plate before continuing with the installation procedure.

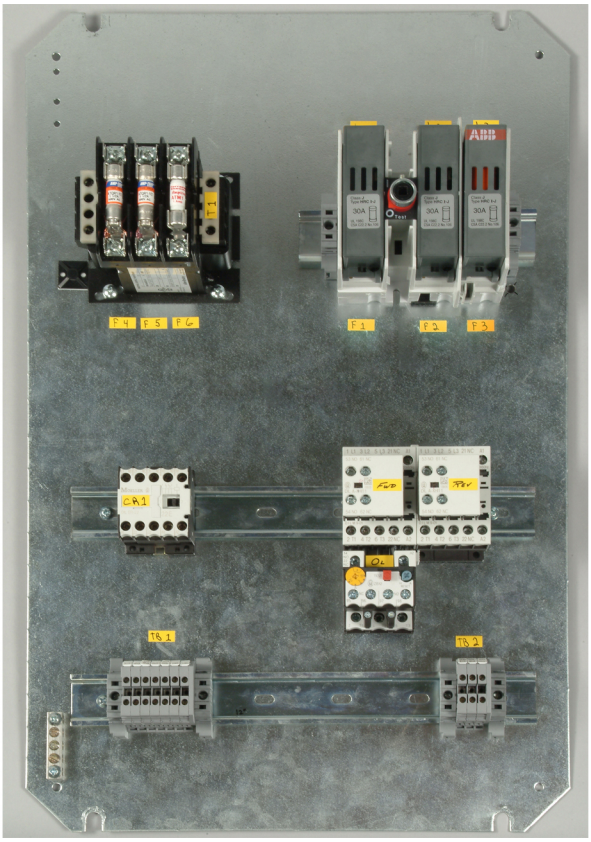

Figure 37. Mounting plate at this stage of the installation procedure.

15. Apply labels to the mounting plate of the motor control enclosure to identify the three power line input terminals (L1, L2, and L3) and the various fuse holders (F1 to F6) as indicated in the connection diagram of the motor control circuit.

16. Apply labels to the three-pole safety switch, the control voltage transformer, the two three-pole contactors, the overload relay, and the control relay to identify these components as indicated in the connection diagram of the motor control circuit.

17. Apply labels to the mounting plate of the motor control enclosure to identify the two terminal blocks as indicated in the connection diagram of the motor control circuit. Identify the terminals of each terminal block as indicated in the connection diagram of the motor control circuit. See Figure 38.

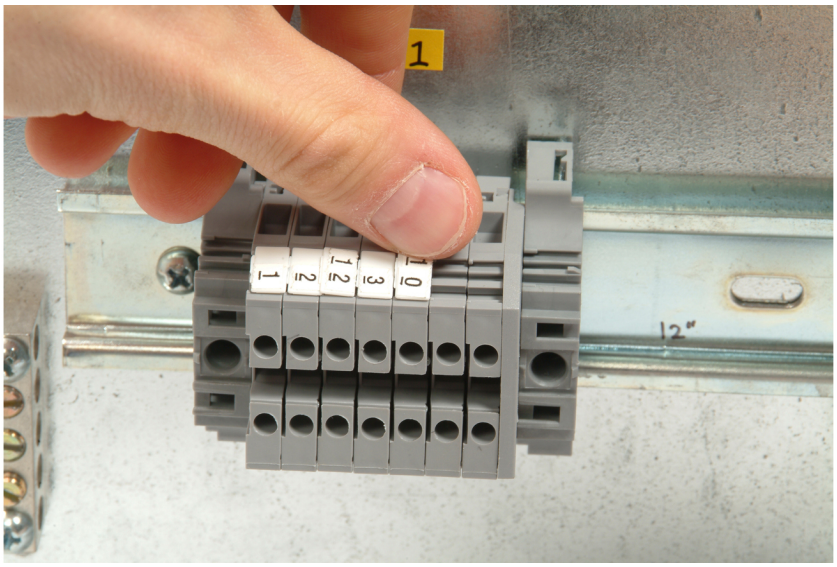

Figure 38. Identify each terminal.

18. Wire the electrical components as indicated in the connection diagram of the motor control circuit, and in compliance with the NEC®.

- Refer to Figure 39 and prepare each wire with care. Cut the wire to the desired length and strip the end using a wire stripper. Do not remove more insulation than required to make a solid connection. Make sure to identify each wire at its two ends with wire marking tape.

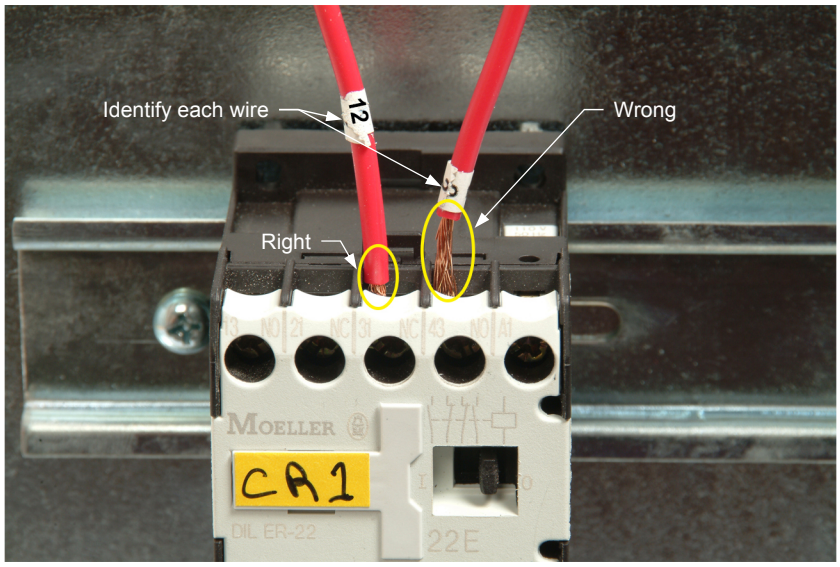

Figure 39. Remove just enough insulation and identify each wire.

- Use conductors of type MTW and size no. 14 AWG, with black insulation, for all connections that can carry current to the door motor and the connection of the control-voltage transformer primary winding.

- Use conductors of type MTW and size no. 16 AWG, with red insulation, for all other connections of the control circuit (control signal connections).

- Use cable ties and adhesive back cable tie mounts to organize your wires neatly on the mounting plate.

Read the following details for the wiring of the overload relay, control voltage transformer and safety switch:

Overload relay

- Note that the overload relay must be temporarily disconnected from the two three-pole contactors when interconnecting terminals T1, T2, and T3 of these contactors. This is shown in Figure 40.

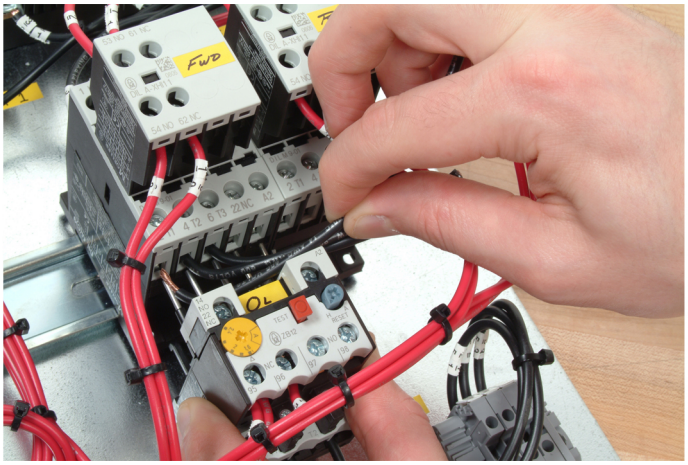

Figure 40. Temporary disconnection of the overload relay allows terminals T1, T2, and T3 of the two three-pole contactors to be interconnected.

Control voltage transformer

- Before trying to wire the transformer, read and understand the connection diagram shown on the side of the transformer. See Figure 41.

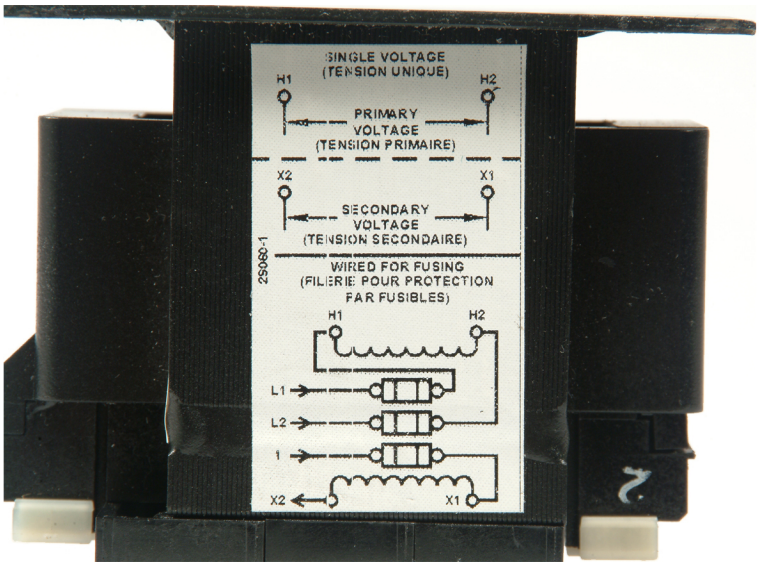

Figure 41. Control voltage transformer connection diagram.

- Refer to Figure 42 and notice that phase L1 (wire 31) is connected to terminal H1 of the transformer through fuse F4. The wire at the bottom right of the figure that connects the fuse to terminal H1 does not need to be identified.

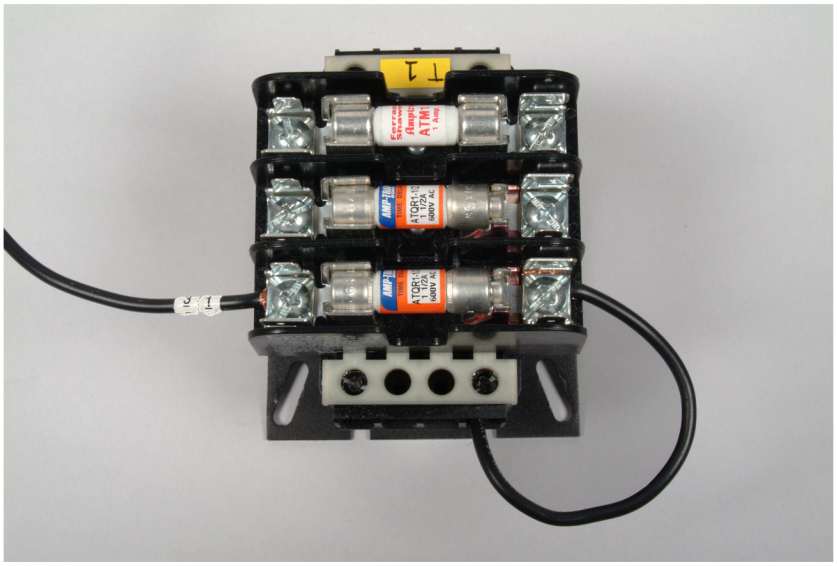

Figure 42. Connection of L1, F4, and H1.

- Refer to Figure 43 and notice that phase L2 (wire 32) is connected to terminal H2 of the transformer through fuse F5. The wire connecting F5 to H2 is not identified.

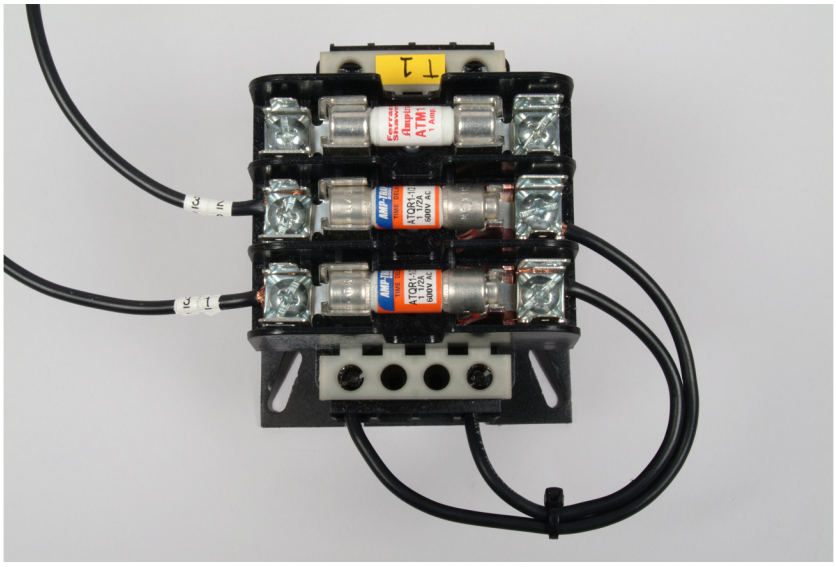

Figure 43. Connection of L2, F5, and H2.

- Refer to Figure 44 and notice how wire 1, wire 8 and fuse F6 are connected to the transformer.

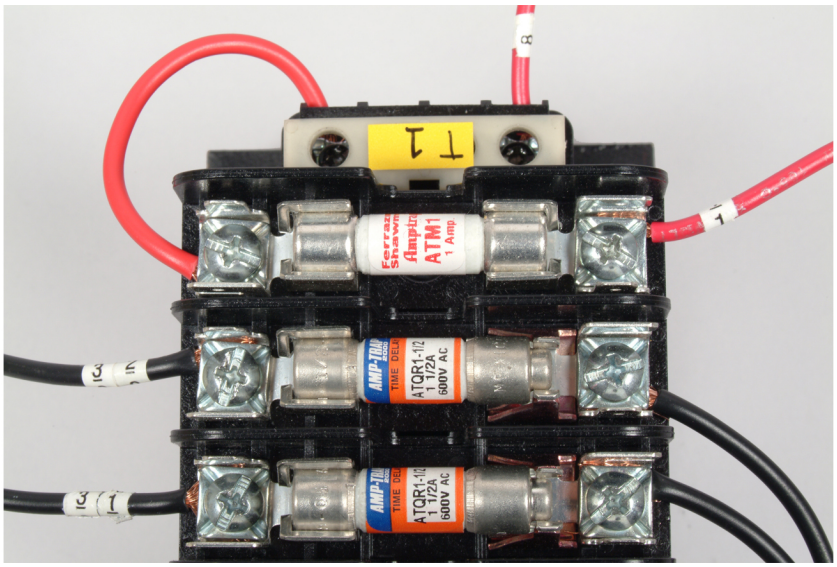

Figure 44. Connection of wire 1 and 8 and F6.

- Use a conductor of type MTW and size no. 16 AWG, with green insulation, to connect terminal X2 of the control voltage transformer to the grounding terminal block of the mounting plate.

Safety switch

- To reach the terminals on the safety switch, you must first remove the fuse holder as shown in Figure 45.

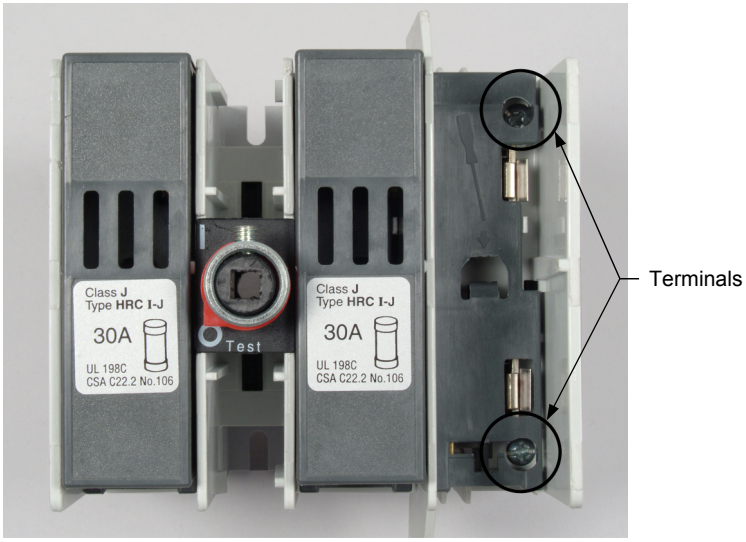

Figure 45. Remove the fuse holder to reach the terminals on the safety switch.

19. Using an ohmmeter as shown in Figure 46, check the connections you made to ensure that the components are wired as in the connection diagram of the motor control circuit.

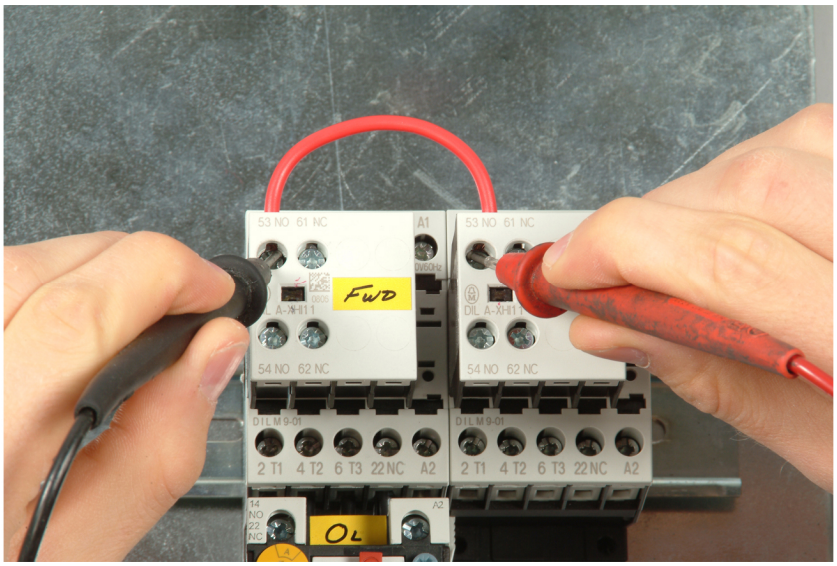

Figure 46. Verify the connections with an ohmmeter.

20. Install the required fuses in the fuse holders of the three-pole safety switch (if this is not already done) and in the fuse holder of the control voltage

transformer. Figure 47 shows the completely assembled motor control circuit with all fuses installed.

Certain electrical components shown in Figure 31 may differ from those used to build the motor control circuit.

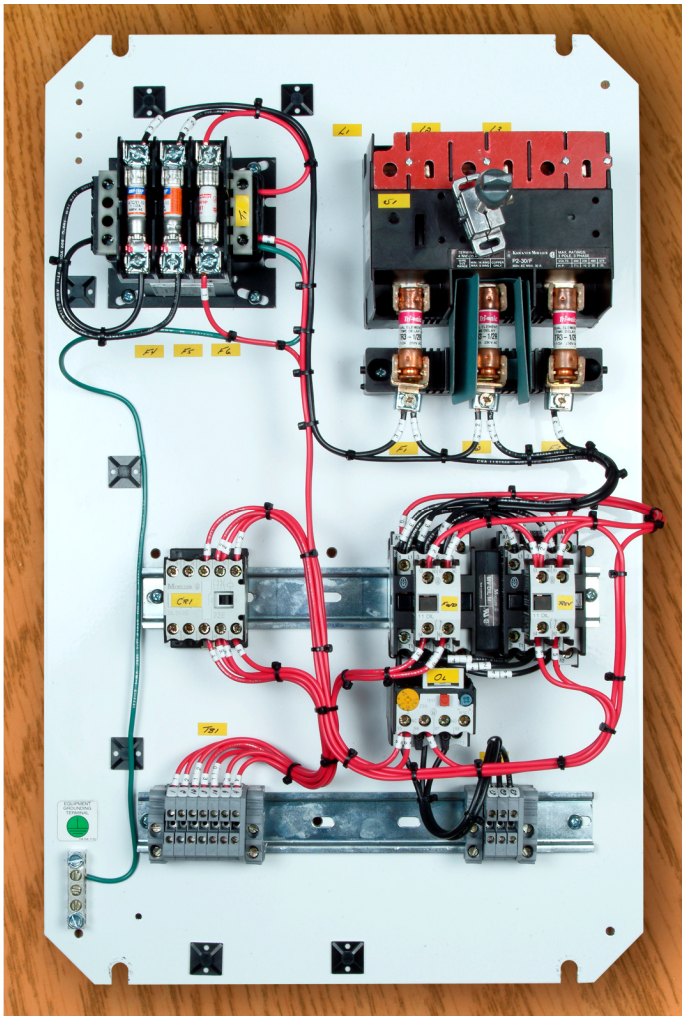

Figure 47. Completely assembled motor control circuit.

21. Refer to Figure 48 and use a screwdriver to set the current of the overload relay to the value indicated in the legend of the schematic diagram of the overhead door simulator.

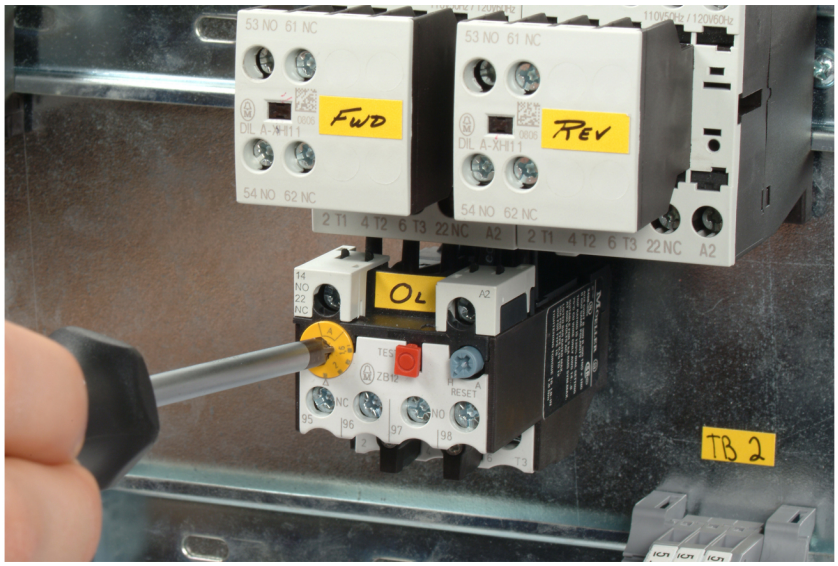

Figure 48. Setting the overload current.

22. Ask your instructor to check and approve your work.

23. Keep the assembled motor control circuit in a storage location. It will be used in a later job sheet.

Student assessment

To assess the student's work, ask questions to verify whether or not he or she understands the following points:

- ❑ The electrical components of the motor control circuit are installed on the mounting plate of the motor control enclosure (MCE) at the locations shown in the connection diagram of the motor control circuit.
- ❑ The fused, three-pole safety switch is positioned on the mounting plate of the MCE so that the axis of the switch's shaft is aligned as closely as possible with the center of the square opening in the MCE door panel. The maximum error on this position is plus or minus 3/8". This tolerance must be respected to allow the installation of the safety switch handle on the MCE door panel (job sheet 8). Note that horizontal alignment is less critical than vertical alignment since the safety switch can be slid horizontally on the DIN rail on which it is installed.
- ❑ The component assembly which consists of the two three-pole contactors and the overload relay is positioned on the mounting plate of the MCE so that the axis of the RESET button on the overload relay is within the lower circular hole in the MCE door panel by at least 1/2". This minimal distance from the outer edge of the circular hole is required for the installation of the motor overload reset button on the MCE door panel

(job sheet 9). Note, however, that close alignment of the RESET button axis with the center of the circular opening provides a "clean" appearance to the MCE door panel when the motor overload reset button is installed.

- ❑ All electrical components of the motor control circuit are securely fastened to the mounting plate of the motor control enclosure.
- ❑ The two three-pole contactors, the mechanical interlocking device, and the two auxiliary contact units are assembled as indicated in Figure 25 of the student manual. The mechanical interlock is operational (i.e., the two contactors cannot be actuated at the same time).
- ❑ Labels applied to the mounting plate of the motor control enclosure identify the three power line input terminals (L1, L2, and L3) and the various fuse holders (F1 to F6) as indicated in the connection diagram of the motor control circuit.
- ❑ Labels applied to the three-pole safety switch, the control voltage transformer, the two three-pole contactors, the overload relay, and the control relay identify these components as indicated in the connection diagram of the motor control circuit.
- ❑ Labels applied to the mounting plate of the motor control enclosure identify the two terminal blocks as indicated in the connection diagram of the motor control circuit.
- ❑ The terminals of each terminal block are identified as indicated in the connection diagram of the motor control circuit.
- ❑ The electrical components are wired as indicated in the connection diagram of the motor control circuit and in compliance with Articles 110, 250, 310, 312, and 430 of the National Electrical Code® (NEC®).
- ❑ Conductors of type MTW and size no. 14 AWG, with black insulation, should be used for all connections that can carry current to the door motor and the connection of the control-voltage transformer primary winding.
- ❑ A conductor of type MTW and size no. 16 AWG, with green insulation, should be used to connect terminal X2 of the control voltage transformer to the grounding terminal block of the mounting plate.
- ❑ Conductors of type MTW and size no. 16 AWG, with red insulation, should be used for all other connections of the control circuit (control signal connections).
- ❑ The setscrews on the pressure terminals are fastened tightly to ensure solid connections of all conductors.
- ❑ The conductors are organized neatly and kept together using proper fasteners (e.g., cable ties).
- ❑ All conductors are identified at each end using wire marking tapes, as indicated in the connection diagram of the motor control circuit.
- ❑ The required fuses (see legend in the schematic diagram of the overhead door simulator for types of fuse required) are installed in the fuse holders of the three-pole safety switch and in the fuse holder of the control voltage transformer.

❑ The current setting of the overload relay is set to the value indicated in the legend of the schematic diagram of the overhead door simulator.

Note to the instructor

- It is your choice to have the electrical components of the motor control circuit installed and wired by the students or by competent personnel in charge of the laboratory equipment. If you choose to have the motor control circuit pre-wired by competent personnel (to avoid wear of or damage to the electrical components), instruct the students to skip this job sheet.

- Completion of this job sheet should require two to four lab sessions (3 hours per session) depending on the student's skills.

Name: _____ Date: _____

Instructor's approval: _____

Sample Work Order

Extracted from

Electrical Wiring

Wiring of the Motor Control Circuit

OBJECTIVE

To install the electrical components of the motor control circuit on the mounting plate of the motor control enclosure. To wire these components according to the connection diagram of the motor control circuit and in compliance with the National Electrical Code® (NEC®).

PROCEDURE

1. Identify the fused, three-pole safety switch. Figure 14 shows an example of this type of safety switch. Notice that the switch shown in Figure 14 is provided with removable fuse holders.

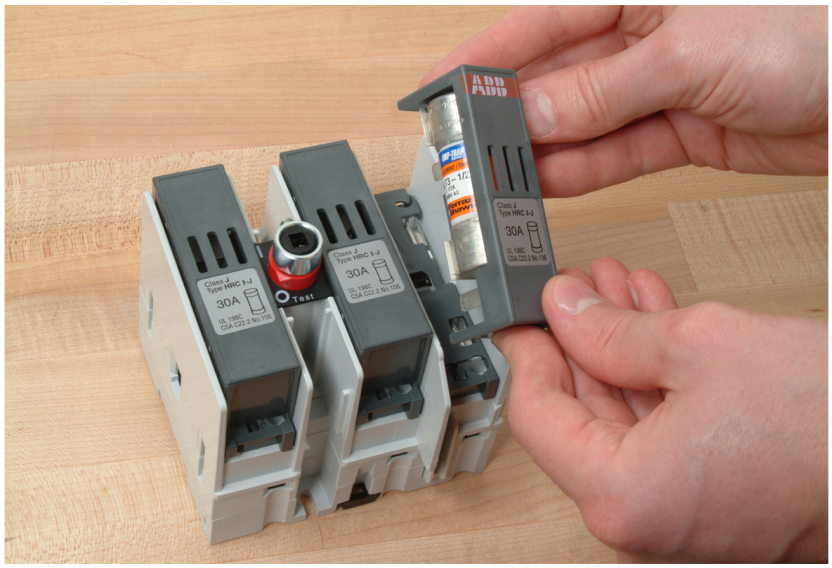

Figure 14. Example of a fused, three-pole safety switch.

The description and part number of each electrical component described in this work order are provided in the Equipment Utilization Chart (Appendix A of this manual).

2. Identify the two three-pole contactors. These consist of two three-pole contactors, a mechanical interlocking device, and two auxiliary contact units, as shown in Figure 15.

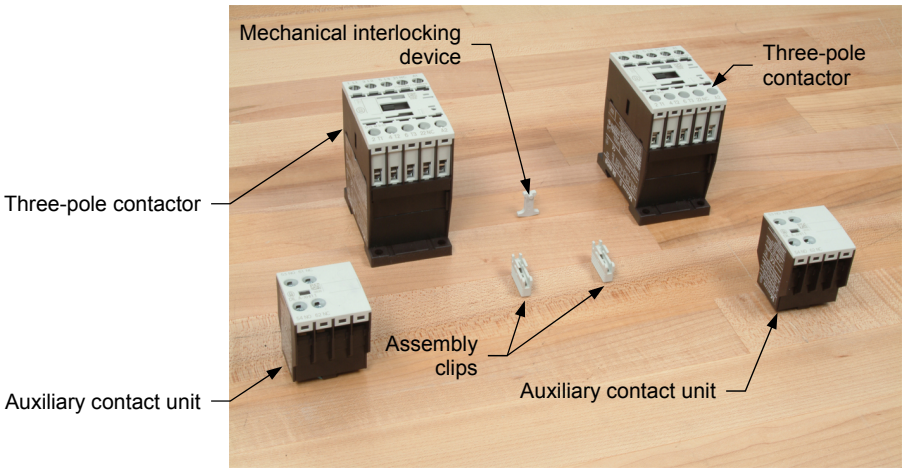

Figure 15. Typical components required to assemble a dual three-pole contactor unit.

A three-pole contactor is easily identified by its main contact terminals which are labeled L1, L2, L3 and T1, T2, T3, as well as its power rating which is expressed in both kilowatts (kW) and horsepower (hp).

An auxiliary contact unit is a small device designed to be attached to a contactor. It has no coil (no terminals labeled A1 and A2) and is actuated by the contactor.

3. Assemble the two three-pole contactors, the mechanical interlocking device, and the two auxiliary contact units as indicated in the diagram of Figure 16.

   Verify that the mechanical interlock is operational.

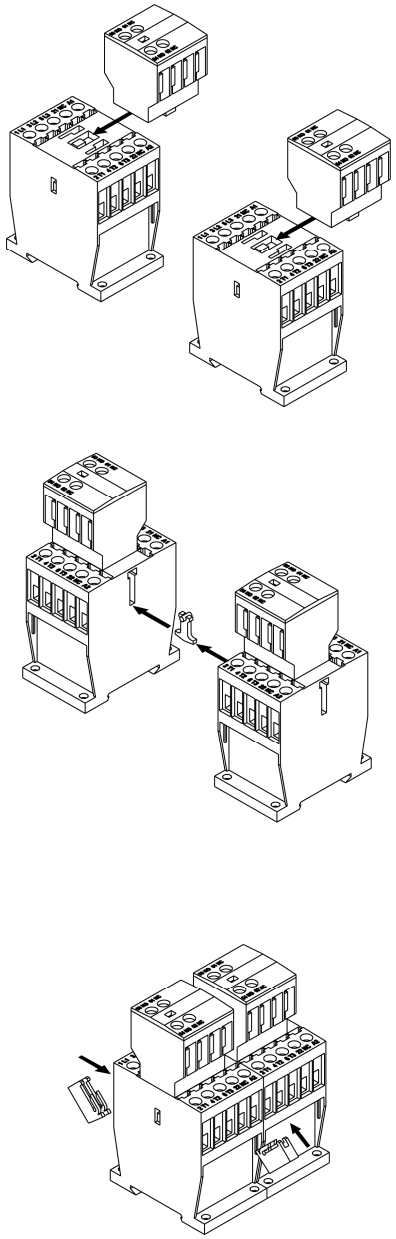

Figure 16. Dual three-pole contactor assembly diagram.

4. Identify the fuse-protected, control voltage transformer. A fuse-protected, control voltage transformer is shown in Figure 17. This kind of transformer is easily recognizable by the fuse holder attached to the unit.

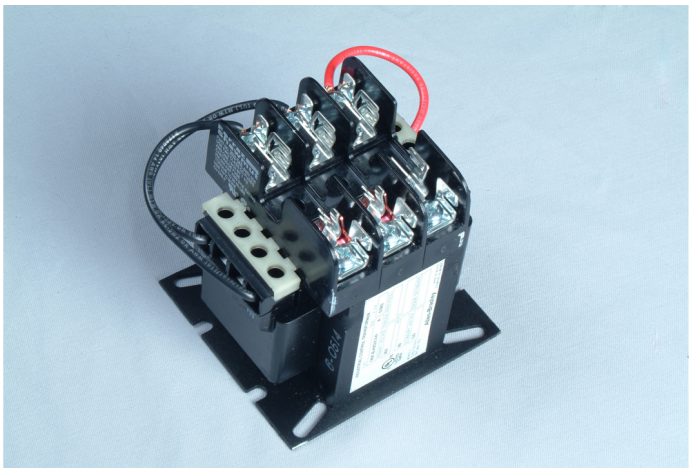

Figure 17. A fuse-protected, control voltage transformer.

5. Identify the overload relay and the control relay. An example of these components is shown in Figure 18.

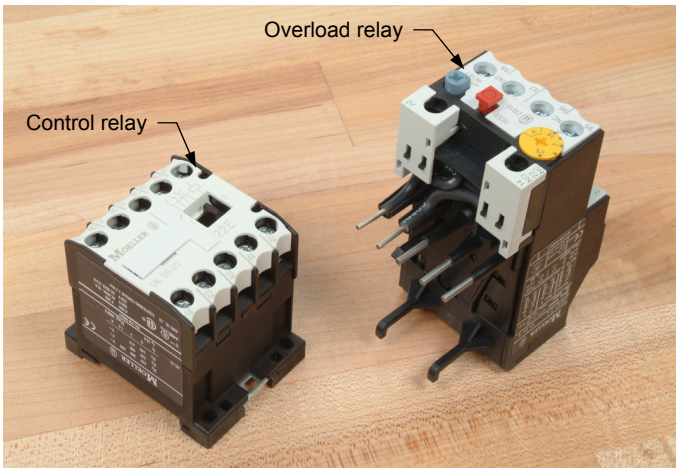

Figure 18. An overload relay and a control relay.

An overload relay is recognized by its current setting knob and reset button. Many overload relays also have a test button.

A control relay is easily identified by its coil terminals which are usually labeled A1 and A2, as well as its contact terminals which are labeled with numbers (e.g., 13 and 14, 21 and 22, 31 and 32, etc.). Its contacts are usually rated in terms of current at a specific voltage.

6. Identify the various items that are required to assemble a terminal block. Figure 19 shows typical terminal block items as well as an assembled terminal block.

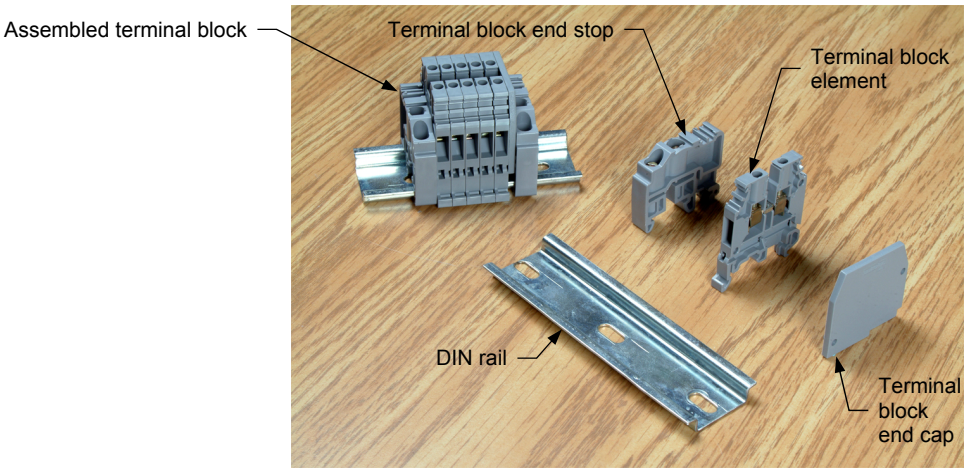

Figure 19. Items required to assemble a terminal block.

7. Remove the mounting plate from the motor control enclosure and place it on a flat surface (e.g., a work bench).

8. Install the fused, three-pole safety switch on the mounting plate of the motor control enclosure (MCE) at the location indicated in the connection diagram of the motor control circuit. Note that the safety switch should be installed on a DIN rail. Before you drill holes in the mounting plate, ask your instructor to check whether or not the location at which you decide to install the three-pole safety switch is correct.

The fused, three-pole safety switch should be positioned on the MCE mounting plate so that the axis of the switch's shaft is aligned as closely as possible with the center of the square opening in the MCE door panel.

9. Install the overload relay on one of the two three-pole contactors that you assembled earlier in this work order. Figure 20 shows how to install an overload relay on a three-pole contactor.

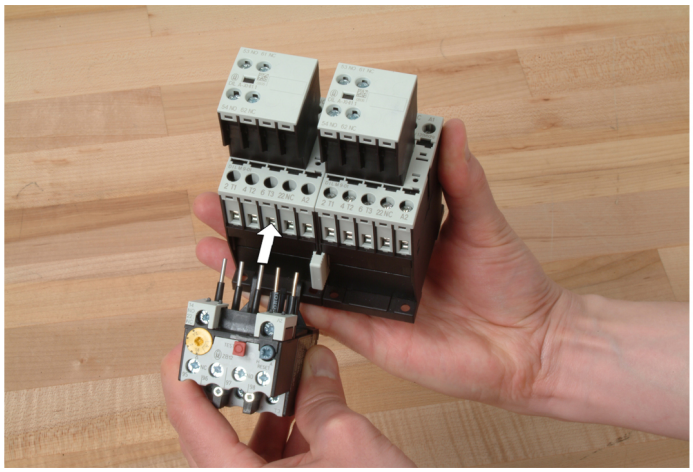

Figure 20. Installing an overload relay on a three-pole contactor.

10. Install the two three-pole contactors and the overload relay on the mounting plate of the motor control enclosure at the location indicated in the connection diagram of the motor control circuit. Before you drill holes in the mounting plate, ask your instructor to check whether or not the location at which you elect to install this component assembly is correct.

The two three-pole contactors and the overload relay should be positioned on the MCE mounting plate so that the axis of the RESET button on the overload relay is aligned with the center of the circular opening in the MCE door panel.

11. Install the other electrical components of the motor control circuit (control voltage transformer, control relay, and terminal blocks) on the mounting plate of the motor control enclosure as indicated in the connection diagram of the motor control circuit.

12. Apply labels to the mounting plate of the motor control enclosure to identify the three power line input terminals (L1, L2, and L3) and the various fuse holders (F1 to F6) as indicated in the connection diagram of the motor control circuit.

13. Apply labels to the three-pole safety switch, the control voltage transformer, the two three-pole contactors, the overload relay, and the control relay to identify these components as indicated in the connection diagram of the motor control circuit.

14. Apply labels to the mounting plate of the motor control enclosure to identify the two terminal blocks as indicated in the connection diagram of the motor control circuit. Identify the terminals of each terminal block as indicated in the connection diagram of the motor control circuit.

15. Wire the electrical components as indicated in the connection diagram of the motor control circuit, and in compliance with the National Electrical Code® (NEC®). Identify each conductor as indicated in the connection diagram of the motor control circuit.

    Note that the overload relay must be temporarily disconnected from the two three-pole contactors when interconnecting terminals T1, T2, and T3 of these contactors. This is shown in Figure 21.

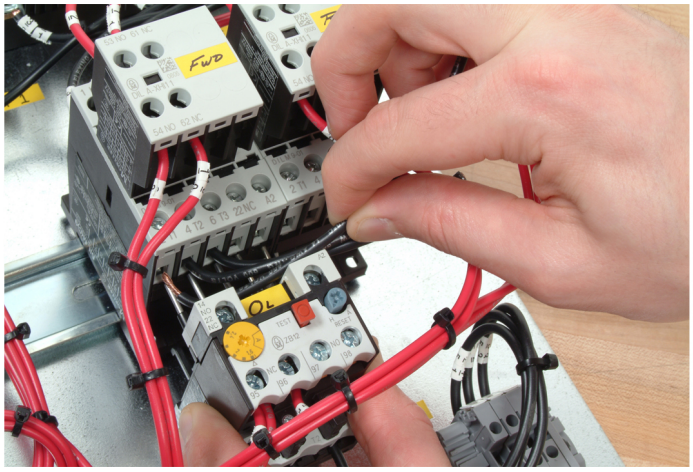

Figure 21. Temporary disconnection of the overload relay allows terminals T1, T2, and T3 of the two three-pole contactors to be interconnected.

16. Using an ohmmeter, check the connections you made to ensure that the components are wired as in the connection diagram of the motor control circuit.

17. Install the required fuses in the fuse holders of the three-pole safety switch (if this is not already done) and in the fuse holder of the control voltage transformer. Figure 22 shows the completely assembled motor control circuit with all fuses installed.

Certain electrical components shown in Figure 22 may differ from those used to build the motor control circuit.

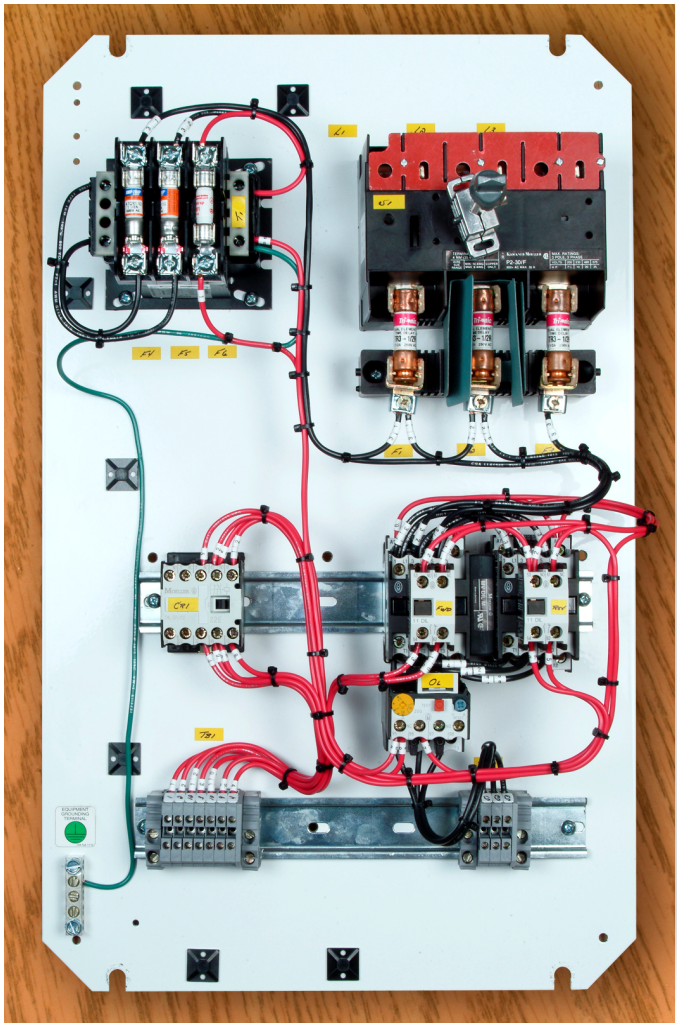

Figure 22. Completely assembled motor control circuit.

18. Set the current setting of the overload relay to the value indicated in the legend of the schematic diagram of the overhead door simulator.

19. Ask your instructor to check and approve your work.

20. Keep the assembled motor control circuit in a storage location. It will be used in a later work order.

Student assessment

The following points should be checked to assess the student's work:

- ❑ The electrical components of the motor control circuit are installed on the mounting plate of the motor control enclosure (MCE) at the locations shown in the connection diagram of the motor control circuit.
- ❑ The fused, three-pole safety switch is positioned on the mounting plate of the MCE so that the axis of the switch's shaft is aligned as closely as possible with the center of the square opening in the MCE door panel. The maximum error on this position is plus or minus 3/8". This tolerance must be respected to allow the installation of the safety switch handle on the MCE door panel (work order 8). Note that horizontal alignment is less critical than vertical alignment since the safety switch can be slid horizontally on the DIN rail on which it is installed.
- ❑ The component assembly which consists of the two three-pole contactors and the overload relay is positioned on the mounting plate of the MCE so that the axis of the RESET button on the overload relay is within the lower circular hole in the MCE door panel by at least 1/2". This minimal distance from the outer edge of the circular hole is required for the installation of the motor overload reset button on the MCE door panel (work order 9). Note, however, that close alignment of the RESET button axis with the center of the circular opening provides a "clean" appearance to the MCE door panel when the motor overload reset button is installed.
- ❑ All electrical components of the motor control circuit are securely fastened to the mounting plate of the motor control enclosure.
- ❑ The two three-pole contactors, the mechanical interlocking device, and the two auxiliary contact units are assembled as indicated in Figure 16. The mechanical interlock is operational (i.e., the two contactors cannot be actuated at the same time).
- ❑ Labels applied to the mounting plate of the motor control enclosure identify the three power line input terminals (L1, L2, and L3) and the various fuse holders (F1 to F6) as indicated in the connection diagram of the motor control circuit.
- ❑ Labels applied to the three-pole safety switch, the control voltage transformer, the two three-pole contactors, the overload relay, and the control relay identify these components as indicated in the connection diagram of the motor control circuit.

- ❑ Labels applied to the mounting plate of the motor control enclosure identify the two terminal blocks as indicated in the connection diagram of the motor control circuit.
- ❑ The terminals of each terminal block are identified as indicated in the connection diagram of the motor control circuit.
- ❑ The electrical components are wired as indicated in the connection diagram of the motor control circuit and in compliance with Articles 110, 250, 310, 312, and 430 of the National Electrical Code® (NEC®).
- ❑ Conductors of type MTW and size no. 14 AWG, with black insulation, should be used for all connections that can carry current to the door motor and the connection of the control-voltage transformer primary winding.
- ❑ A conductor of type MTW and size no. 16 AWG, with green insulation, should be used to connect terminal X2 of the control voltage transformer to the grounding terminal block of the mounting plate.
- ❑ Conductors of type MTW and size no. 16 AWG, with red insulation, should be used for all other connections of the control circuit (control signal connections).
- ❑ The setscrews on the pressure terminals are fastened tightly to ensure solid connections of all conductors.
- ❑ The conductors are organized neatly and kept together using proper fasteners (e.g., cable ties).
- ❑ All conductors are identified at each end using wire marking tapes, as indicated in the connection diagram of the motor control circuit.
- ❑ The required fuses (see legend in the schematic diagram of the overhead door simulator for types of fuse required) are installed in the fuse holders of the three-pole safety switch and in the fuse holder of the control voltage transformer.
- ❑ The current setting of the overload relay is set to the value indicated in the legend of the schematic diagram of the overhead door simulator.

Note to the instructor

- It is your choice to have the electrical components of the motor control circuit installed and wired by the students or by competent personnel in charge of the laboratory equipment. If you choose to have the motor control circuit pre-wired by competent personnel (to avoid wear of or damage to the electrical components), instruct the students to skip this work order.
- Completion of this work order should require two to four lab sessions (3 hours per session) depending on the student's skills.

Name: _____ Date: _____

Instructor's approval: _____

Wiring of the Overhead Door Simulator

OBJECTIVE

To wire the various electrical components of the overhead door simulator according to the corresponding interconnection diagram and in compliance with the National Electrical Code® (NEC®).

PROCEDURE

1. Wire the various electrical components of the overhead door simulator (motor control circuit, door motor, limit switches, and push-button station) as indicated in the interconnection diagram of the overhead door simulator, and in compliance with the National Electrical Code® (NEC®).

2. Identify the control signal wires (red-insulation conductors) installed in the various conduits as indicated in the interconnection diagram of the overhead door simulator. The conductors of the retractile cord should also be identified.

3. Using an ohmmeter, check the connections you made to ensure that the components are wired as in the interconnection diagram of the overhead door simulator.

4. Ask your instructor to check and approve your work.

5. Keep your equipment setup. You will resume the construction of the overhead door simulator in the next work order.

Student assessment

The following points should be checked to assess the student's work:

- ❑ The electrical components (motor control circuit, door motor, limit switches, and push-button station) are wired as indicated in the interconnection diagram of the overhead door simulator, and in compliance with Articles 110, 250, 300, 310, 312, and 430 of the National Electrical Code® (NEC®). See figures A to F below.
- ❑ The control signal wires (red-insulation conductors) installed in the various conduits and the conductors of the retractile cord are identified as indicated in the interconnection diagram of the overhead door simulator. Each conductor should be identified at both ends. See figures A to E below.

The conductors supplying power to the door motor do not have to be identified with wire marking tapes. These conductors, which are on a separate terminal block, are identified using the colors of their insulation (red, black, and blue).

- ❑ The setscrews on the pressure terminals are fastened tightly to ensure solid connections of all conductors.
- ❑ The conductors are organized neatly and kept together using proper fasteners (e.g., cable ties).
- ❑ A grounding wire (green insulation conductor) is securely fastened to the back wall of the junction box (see Figure B below).
- ❑ A grounding wire (green insulation conductor) is securely fastened to the push-button station enclosure, as shown in Figure C below.
- ❑ A grounding wire (green insulation conductor) should be securely fastened to the door panel of the motor control enclosure, even if it is not absolutely required (see Figure A below).
- ❑ At the junction box, the green insulation conductor of the retractile cord is connected to the ground (green-yellow) terminal block element of terminal block TB4. At the safety limit switch (LS3), this conductor is not required because the switch is double insulated. This end of the green insulation conductor is thus terminated with vinyl electrical tape.
- ❑ The electrical connections at the door motor should be made with #1 solderless connectors (wire nuts).
- ❑ A grounding wire (green insulation conductor) should be securely fastened to the door motor enclosure, as shown in Figure F below.

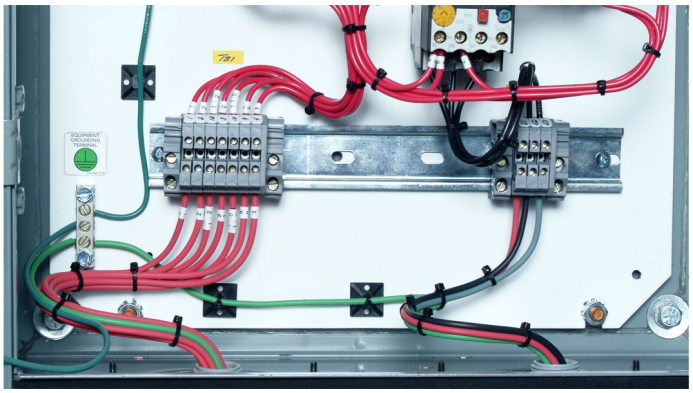

Figure A. Connections in the motor control enclosure of the overhead door simulator.

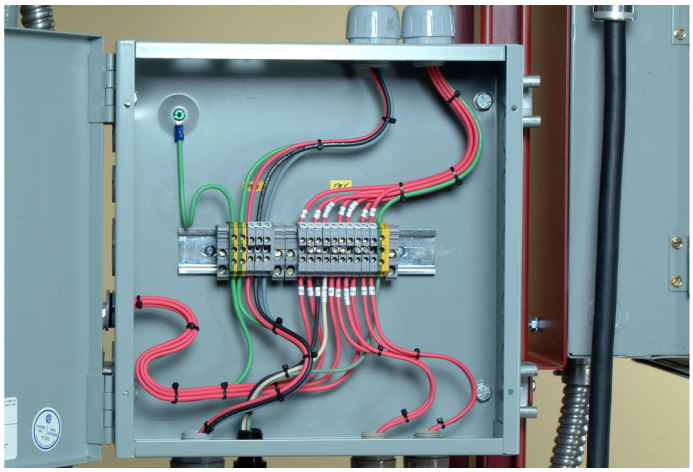

Figure B. Connections in the junction box of the overhead door simulator.

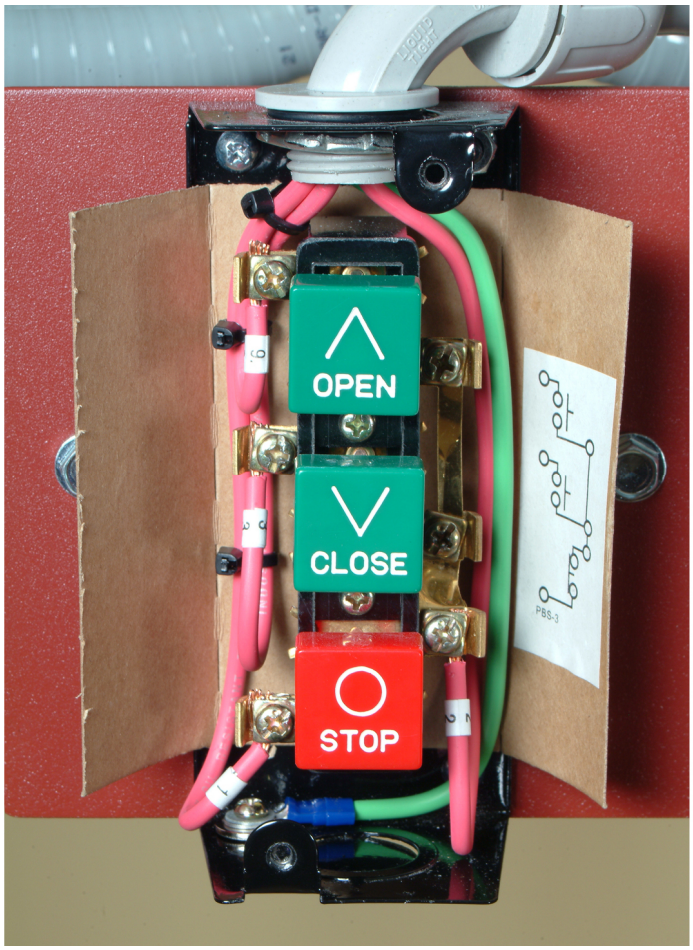

Figure C. Connections in the push-button station of the overhead door simulator.

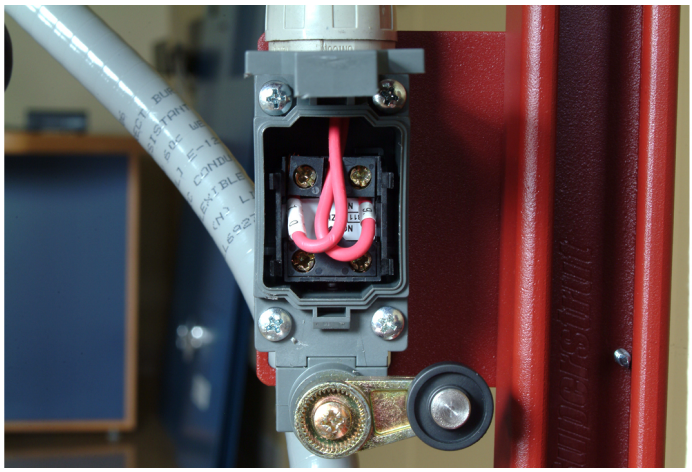

Figure D. Connections in the upper limit switch (LS2) of the overhead door simulator (connections in the lower limit switch [LS1] are identical).

Figure E. Connections in the safety limit switch (LS3) of the overhead door simulator.

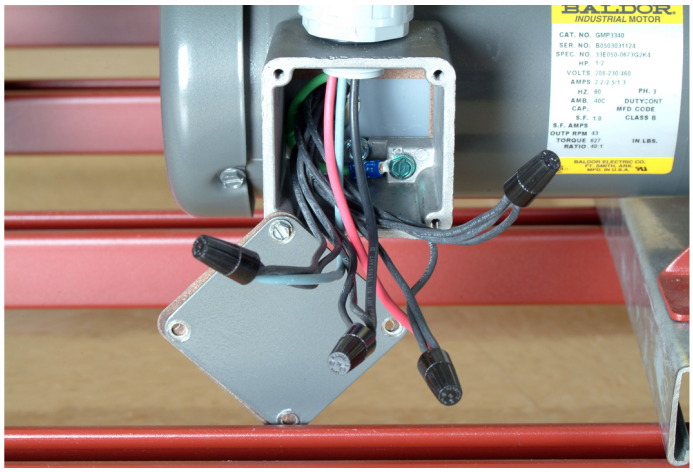

Figure F. Connections at the door motor of the overhead door simulator.

Name: _____ Date: _____

Instructor's approval: _____