

Industrial Maintenance

Enclosures and Conduits

Courseware Sample

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By the staff of Festo Didactic

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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 indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
	WARNING indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
	CAUTION indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
	CAUTION used without the <i>Caution, risk of danger</i> 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 electrical enclosures and conduits. When you have completed these job sheets, you will be able to interconnect electrical enclosures and boxes with various types of conduit.

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

Refer to the Electrical Level One – Trainee Guide from the National Center for Construction Education and Research (NCCER).

Also refer to the articles of the National Electrical Code® (NEC®) that are mentioned in the various modules of the NCCER's manuals listed above.

Appendices

Appendix A, *Equipment Utilization Chart*, indicates the components, specialized tools, and consumable goods (flexible metal conduit, electrical metallic tubing, cutting oil, 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, *Reference Tables*, contains the values required to perform the calculations for bends in various conduits.

Appendix E, *Reference Material*, lists references to sections and modules of the Electrical Trainee Guide from the NCCER. These references provide the information and theory necessary to perform the job sheets in this manual.

About This Manual

Appendix F, *Parts List*, lists all the parts in the Enclosure and Conduits set, Model 46810.

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.

Sample Job Sheet
Extracted from
Enclosures and Conduits

Conduit Bending – Saddle Bends

OBJECTIVE To make three-bend saddles on 1/2" and 3/4" electrical metallic tubing (EMT).

- PROCEDURE**
1. Perform the basic safety procedures listed in Appendix C of this manual.
 2. Read reference 4 (see Appendix E) for more information on bends.
 3. Cut a piece of 1/2" EMT to a length of 60". Ream the inside edges of your piece of EMT using the nose of diagonal cutters.
 4. Make the bends required on your piece of 1/2" EMT to obtain a three-bend saddle that can clear a 2 1/4" circular obstruction and is located in the middle of the piece of EMT, as shown in Figure 40. To do so:



Figure 40. A three-bend saddle deep enough to clear a 2 1/4" obstruction (performed on a piece of 1/2" EMT).

- Determine the location of the center of the saddle (Mark A). In this case, use the real center of the conduit. Do not take the shrinkage into account to determine the center. Enter this result and the following one in Table 6.



Usually the center mark is moved forward by the amount of shrinkage due the three bends. Manufacturers provide a table showing the shrinkage values. This is NOT taken into account in this example.

Table 6. Location of the three required marks for the saddle bend.

Location of center Mark A	A — B and A — C distance

- Multiply the saddle depth by 2.5 to obtain the A — B and A — C distances as shown in Figure 41.

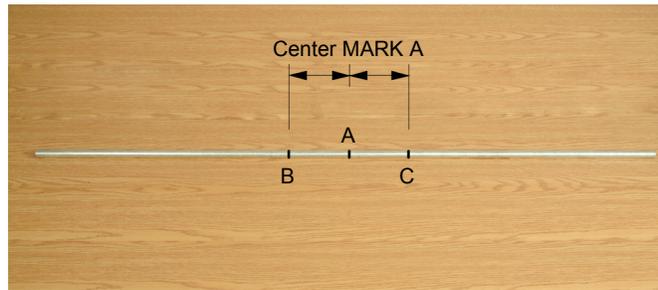


Figure 41. Mark A, B and C on the conduit.

- Draw marks A, B and C on the conduit at the location you just determined.



Make sure to draw the mark completely around the conduit to avoid losing sight of the mark while performing the bend.

- Summarize your results in Table 6 and ask your instructor to verify them before bending.
- Select the bender designed for 1/2" EMT. Feed the conduit in the bender and line up bending Mark A on the conduit with the two NOTCHES near the star on the bender shoe as shown in Figure 42.

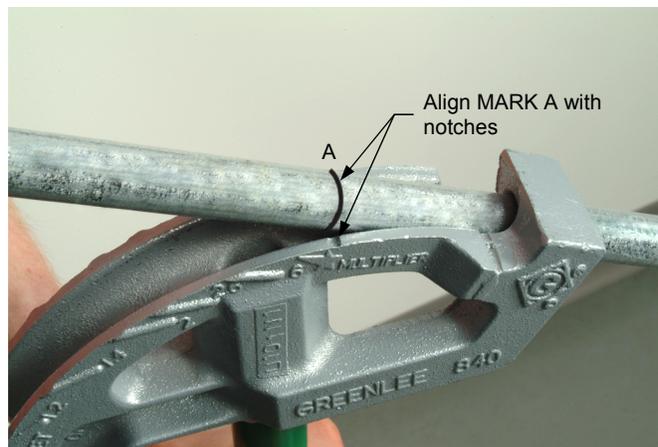


Figure 42. Line up Mark A with notches.

- Bend the conduit at this location until you reach a 45° angle as shown in Figure 43.



You may need to overbend the conduit to compensate for spring back.

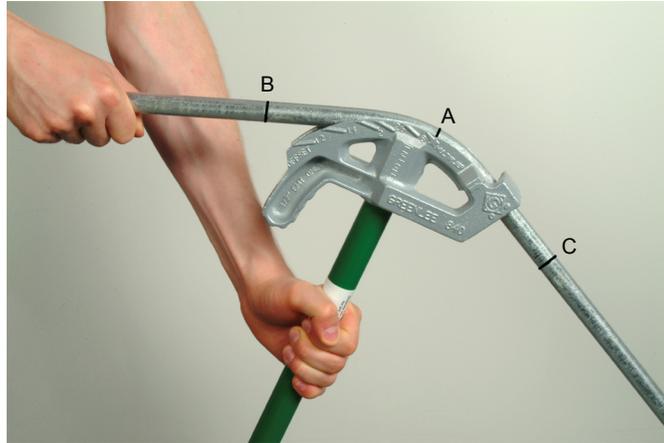


Figure 43. Bend the conduit until you reach a 45° angle.

- Roll the conduit 180° and feed it in the bender shoe until Mark B is lined up with the ARROW as shown in Figure 44.

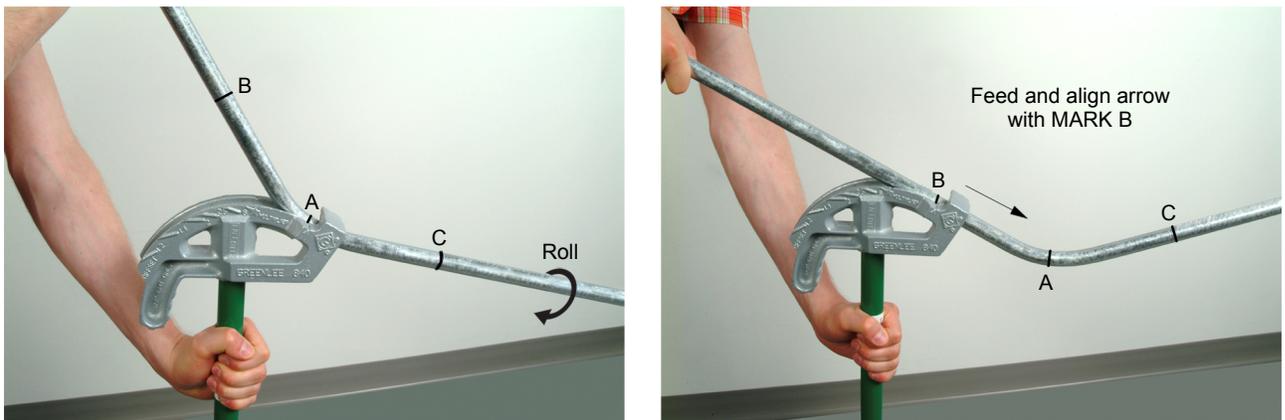


Figure 44. Line up Mark B with the arrow.

- Make sure the bender is in line with the center 45° bend and bend the conduit at this location until you reach a 22 1/2° angle as shown in Figure 45.

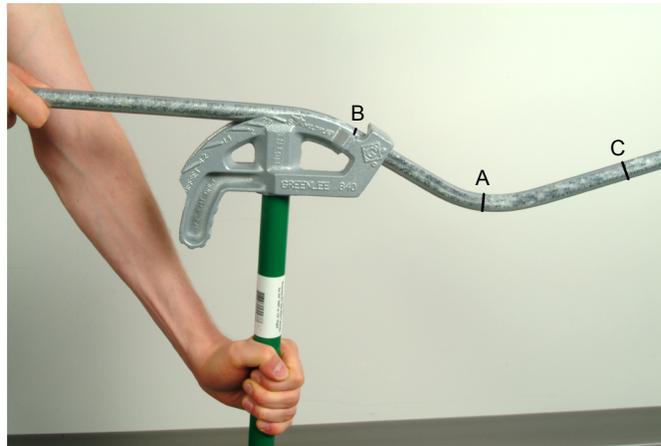


Figure 45. Bend the conduit until you reach a 22 1/2° angle.

- Reverse the conduit in the bender shoe, line up the arrow with Mark C and bend the conduit at this location until you reach a 22 1/2° angle as shown in Figure 46.

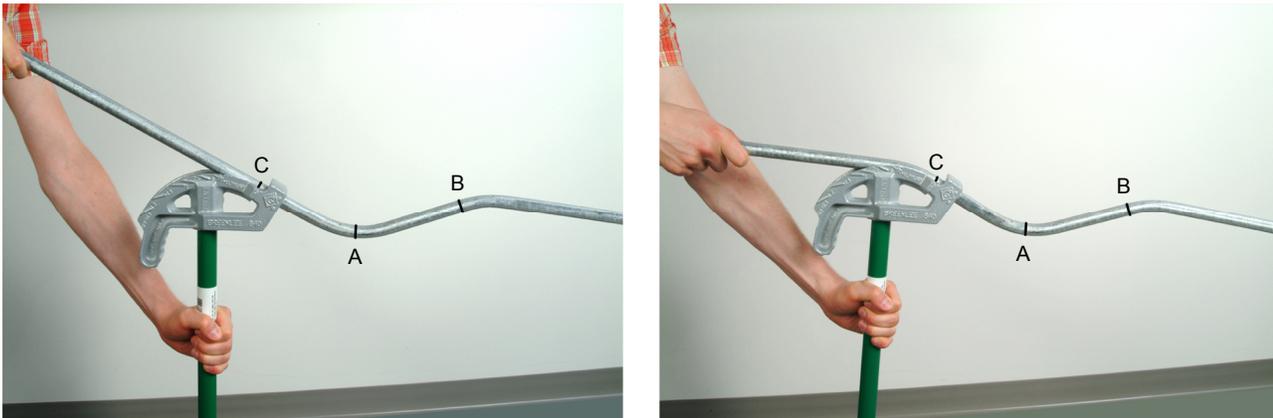


Figure 46. Reverse the conduit in the bender shoe and line up Mark C with the arrow.

5. Cut a piece of 3/4" EMT to a length of 60". Ream the inside edges of your piece of 3/4" EMT.

6. Make the bends required on your piece of 3/4" EMT to obtain a three-bend saddle that can clear a 2" circular obstruction and is located in the middle of the piece of EMT, as shown in Figure 47. To do so:



Figure 47. A three-bend saddle deep enough to clear a 2" obstruction (performed on a piece of 3/4" EMT).

- Perform the calculations to determine the location of the marks and summarize your results in Table 7. Ask your instructor to verify them before bending.

Table 7. Location of the three required marks for the saddle bend.

Location of center Mark A	A — B and A — C distance

- Select the bender designed for 3/4" EMT and bend the conduit at the three bending marks you determined. Make sure to line up Mark A with the two notches and marks B and C with the arrow on the bender shoe.

7. Ask the instructor to check and approve your work.

Student assessment

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

Saddle for a 2 1/4" circular obstruction located 20" away from one end of a piece of 1/2" EMT conduit

- The saddle depth is 2 1/4".
- The bends are made so that the tubing is not damaged and the internal diameter of the tubing is not effectively reduced, as stated in Article 358 of the National Electrical Code® (NEC®).
- The center bend is a 45° bend and the two outer bends are 22.5° bends.
- Both ends of the piece of EMT are cut and reamed properly (i.e. the ends of the conduit are straight and smooth).

Table 6. Location of the three required marks for the saddle bend.

Location of center Mark A	A — B and A — C distance
30"	5 5/8"

Saddle for a 2" circular obstruction located 24" away from one end of a piece of 3/4" EMT conduit

- The saddle depth is 2".
- The bends are made so that the tubing is not damaged and the internal diameter of the tubing is not effectively reduced, as stated in Article 358 of the National Electrical Code® (NEC®).
- The center bend is a 45° bend and the two outer bends are 22.5° bends.
- Both ends of the piece of EMT are cut and reamed properly (i.e. the ends of the conduit are straight and smooth).

Table 7. Location of the three required marks for the saddle bend.

Location of center Mark A	A — B and A — C distance
30"	5"

Name: _____ Date: _____

Instructor's approval: _____

Sample Work Order
Extracted from
Enclosures and Conduits

Conduit Bending – Saddle Bends

OBJECTIVE To make three-bend saddles on 1/2" and 3/4" electrical metallic tubing (EMT).

PROCEDURE

1. Figure 30 shows the markings on the bending shoe of a typical hand bender (GreenLee® Site-Rite II® 841) that are used when performing the center bend of a saddle.

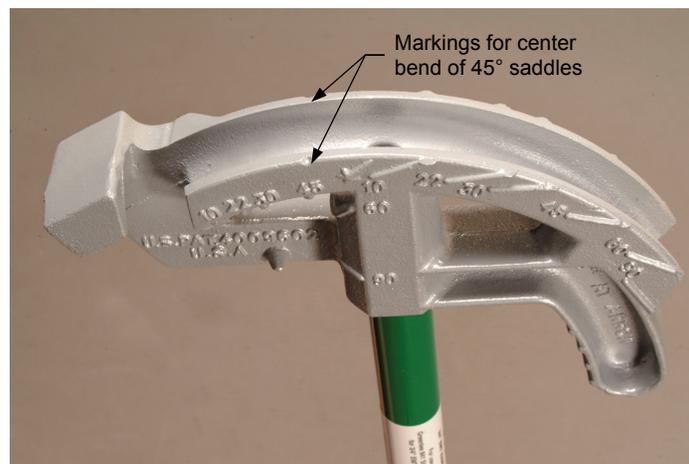


Figure 30. Markings on the bending shoe of a typical hand bender (GreenLee® Site-Rite II® 841) that are used when performing the center bend of a saddle.

2. Cut a piece of 1/2" EMT to a length of 40". Ream the inside edges of your piece of 1/2" EMT.

3. Make the bends required on your piece of 1/2" EMT to obtain a three-bend saddle that can clear a 2 1/4" circular obstruction and is located in the middle of the piece of EMT, as shown in Figure 31.



The conduit outside diameter should be added to the size of the obstruction when determining the saddle depth.



Figure 31. A three-bend saddle deep enough to clear a 2 1/4" obstruction (performed on a piece of 1/2" EMT).

4. Cut a piece of 3/4" EMT to a length of 48". Ream the inside edges of your piece of 3/4" EMT.
5. Make the bends required on your piece of 3/4" EMT to obtain a three-bend saddle that can clear a 2" circular obstruction and is located in the middle of the piece of EMT, as shown in Figure 32.

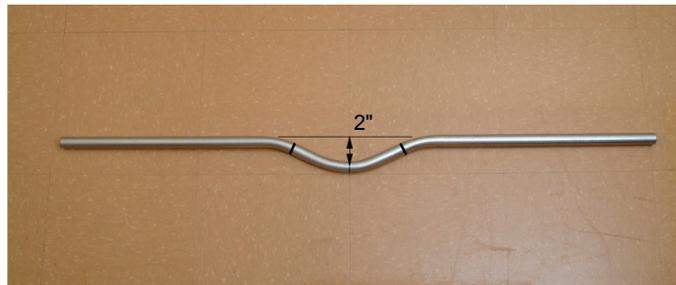


Figure 32. A three-bend saddle deep enough to clear a 2" obstruction (performed on a piece of 3/4" EMT).

6. Ask the instructor to check and approve your work.

Student assessment

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

Saddle for a 2 1/4" circular obstruction:

- The saddle depth (outside measurement) is 2 1/4".
- The middle of the saddle (indicated by the center bending mark) is located in the middle of the piece of 1/2" EMT conduit.
- The bends are made so that the tubing is not damaged and the internal diameter of the tubing is not effectively reduced, as stated in Article 358 of the National Electrical Code® (NEC®).
- The distance between the center mark and each of the two outer bending marks is 5 5/8".
- The center bend is a 45° bend and the two outer bends are 22.5° bends.
- Both ends of the piece of EMT are cut and reamed properly (i.e. the ends of the conduit are straight and smooth).

Saddle for a 2" circular obstruction:

- The saddle depth (outside measurement) is 2".
- The middle of the saddle (indicated by the center bending mark) is located in the middle of the piece of 3/4" EMT conduit.
- The bends are made so that the tubing is not damaged and the internal diameter of the tubing is not effectively reduced, as stated in Article 358 of the National Electrical Code® (NEC®).
- The distance between the center mark and each of the two outer bending marks is 5".
- The center bend is a 45° bend and the two outer bends are 22.5° bends.
- Both ends of the piece of EMT are cut and reamed properly (i.e. the ends of the conduit are straight and smooth).

Name: _____ Date: _____

Instructor's approval: _____

Installing Electrical Metallic Tubing

OBJECTIVE To interconnect enclosures and boxes with electrical metallic tubing (EMT).

PROCEDURE

1. Figure 33 shows 1/2" and 3/4" electrical metallic tubing (EMT) and the corresponding fittings.



Figure 33. 1/2" and 3/4" electrical metallic tubing (EMT) and the corresponding fittings (setscrew type).

2. To make an EMT-to-enclosure connection:

- Insert one end of the EMT into the sleeve of the fitting (see Figure 34).
- Make sure that the EMT is properly seated in the fitting, then tighten the setscrew (see Figure 34).



Figure 34. Installing a fitting to one end of a piece of EMT.

- Unscrew the lock nut of the fitting.
- Insert the EMT and fitting assembly in the opening cut in the enclosure or box wall, then secure the assembly using the lock nut as shown in Figure 35.



The EMT and fitting assembly should be oriented so that the setscrew head is easily accessible.



Figure 35. Securing an EMT and fitting assembly to an enclosure or box wall using a lock nut.

3. Install the metal struts required on the Mobile Workstation, then install dummy enclosures and a dummy box as shown in Figure 36.

4. Interconnect the dummy enclosures and box installed on the Mobile Workstation with EMT, as shown in Figure 36.



Figure 36. Dummy enclosures and box interconnected with 1/2" and 3/4" EMT.

5. Ask the instructor to check and approve your work.
6. Remove the EMT that you installed but leave the dummy enclosures and box on the Mobile Workstation. They will be used in another Work Order.

Student assessment

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

- The dummy enclosures and the dummy box are positioned as shown in Figure 36.
- The dummy enclosures and the dummy box are interconnected with electrical metallic tubing (EMT) as shown in Figure 36.
- The bends are made so that the tubing is not damaged and the internal diameter of the tubing is not effectively reduced, as stated in Article 358 of the National Electrical Code® (NEC®).
- Each hole for conduit connection is centered in the enclosure or box wall.
- The enclosure and box walls where holes have been cut are not buckled.
- A fitting for EMT is used for each conduit-to-enclosure (or conduit-to-box) connection.
- Each fitting is oriented so that the setscrew head is easily accessible.
- The setscrew on each fitting is tightened firmly.
- Each fitting is secured tightly to the enclosure or box wall using a lock nut.
- Both ends of each piece of EMT are cut and reamed properly (i.e. the ends of the conduit are straight and smooth).
- Both ends of each piece of EMT are properly seated in the fittings.



Each conduit-to-enclosure (or conduit-to-box) connection has to be dismantled carefully to check the last two items in the above list.

Name: _____ Date: _____

Instructor's approval: _____