Mechatronics

PLC Applications
Bottling Process

Job Sheets - 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
3∼	Three-phase alternating current

Safety and Common Symbols

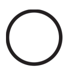
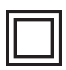
Symbol	Description
	Earth (ground) terminal
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

Table of Contents

Preface

The *Programmable Logic Controller, Basic Programming* student manual allowed the reader to become familiar with PLCs and ladder programming. This was accomplished with the help of the Programmable Logic Controller Training System (Model 3240).

The aim of the present series of PLC applications is to integrate the basic principles previously acquired by designing small-scale systems that can be found in the real world. Through practical examples, students will gain a strong knowledge of the PLC field of study.

Each manual of the PLC applications series concentrates on a specific example of PLC application that evolves along a path of increasing complexity. With each manual, new components are added to the PLC module to create different opportunities to learn.

We hope that your learning experience with the PLC Training System will be the first step of a successful career.

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

Programmable Logic Controllers (PLC's) represent state-of-the-art microprocessor-based electronics that make up technologically advanced control systems with applications in virtually every segment of industry where automation is required.

The present manual includes five Job Sheets that introduce students to PLC control of the Bottling-Process Training System, Model 8075-7. Throughout the manual, students will learn how to program, connect, operate, and troubleshoot different configurations. For optimum operating conditions, the incoming air pressure should be set between 550 kPa (80 psi) and 690 kPa (100 psi).

Prerequisite

Before performing the Job Sheets in this manual, it is recommended to review the *Programmable Logic Controller, Basic Programming* student manual, which explains how to use the programming software and the most common PLC instructions. If any difficulty is encountered while performing the exercises, the programming software's user guide and help menu can assist students in problem solving.

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.

Bottling-Process Training Systems can be harmful when not used properly. Before performing any of the exercises in this manual, make sure that you respect the following general guidelines:

- Put your safety glasses on.
- Avoid wearing any loose clothing (e.g., tie, long sleeves, jewelry).
- Have your hair tied out of the way if it is long.
- Clean your work area if necessary.

Remember that you should never perform an exercise if you have any reason to think that a manipulation could be dangerous to you or your teammates.

Systems of units

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

Appendices

Appendix A: *List of Equipment Required*, gives the list of equipment needed to perform the exercises.

Appendix B: *Ladder Program Design*, presents two different methods that can be employed to program a PLC ladder program.

Appendix C: *Boolean Algebra and Digital Logic*, shows the logical relationships that can be employed with normally-open (NO) and normally-closed (NC) contacts.

Appendix D: *Troubleshooting Procedures*, is a set of guidelines permitting students to locate and correct PLC system failures.

Appendix E: *Glossary of Terms*, defines technical words and expressions contained in this manual.

Appendix F: *Ladder Diagram Graphic Symbols*, depicts the main symbols used in ladder diagrams.

Appendix G: *Hydraulics and Pneumatics Graphic Symbols*, depicts the main symbols related to the hydraulic and pneumatic application fields.

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.

The instructor should be familiar with PLCs to recognize erroneous results. It is advised that a complete run-through of each job sheet be included in the instructor's preparation for class. Each Job Sheet has several performance objectives. The instructor should ensure that each student understands them.

Sample
Extracted from
the Job Sheets Student
and the Job Sheets Instructor

Familiarization with the Bottling-Process Training System

The Bottling-Process Training System is a PLC application designed to practice circular motion control. Figure 1 shows the Power Supply, the PLC, the Stepper Motor drive, and the directional valve used to control the bottling process.

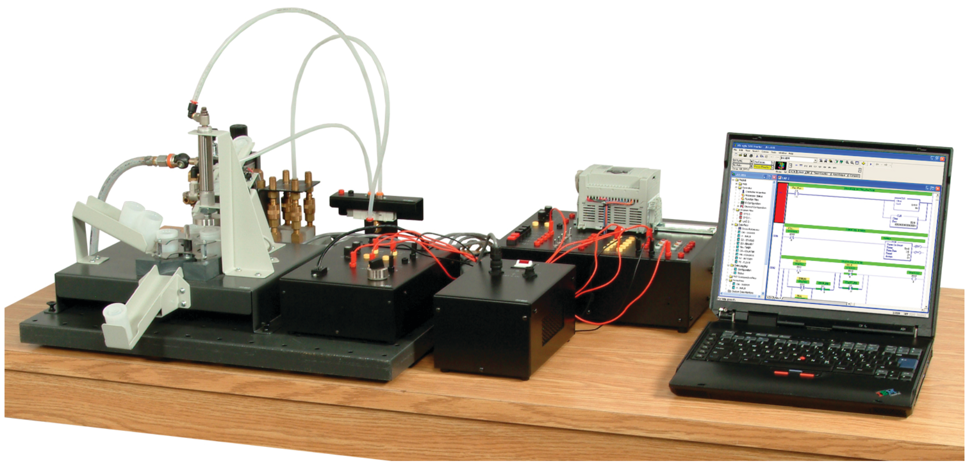


Figure 1. The Bottling-Process Training System.

Motion control

The sub-field of automation pertaining to position and/or speed regulation is called motion control. Motion control is widely used in the packaging, printing, textile and assembly industries. It also plays an important role in robotics and CNC (computer numerical control) machine tools. A typical motion control system contains:

- A motion controller (e.g. a PLC).
- A drive or amplifier to transform the control signal (often desired velocity or torque signal) into a higher power output.
- An actuator such as a hydraulic pump, air cylinder, linear actuator, or electric motor for output motion.
- A feedback sensor such as an optical encoder, or proximity switch to return the position of the actuator to the motion controller.
- Mechanical components (gears, bearings, lead screw, etc.) to transform the motion of the actuator into the desired motion.

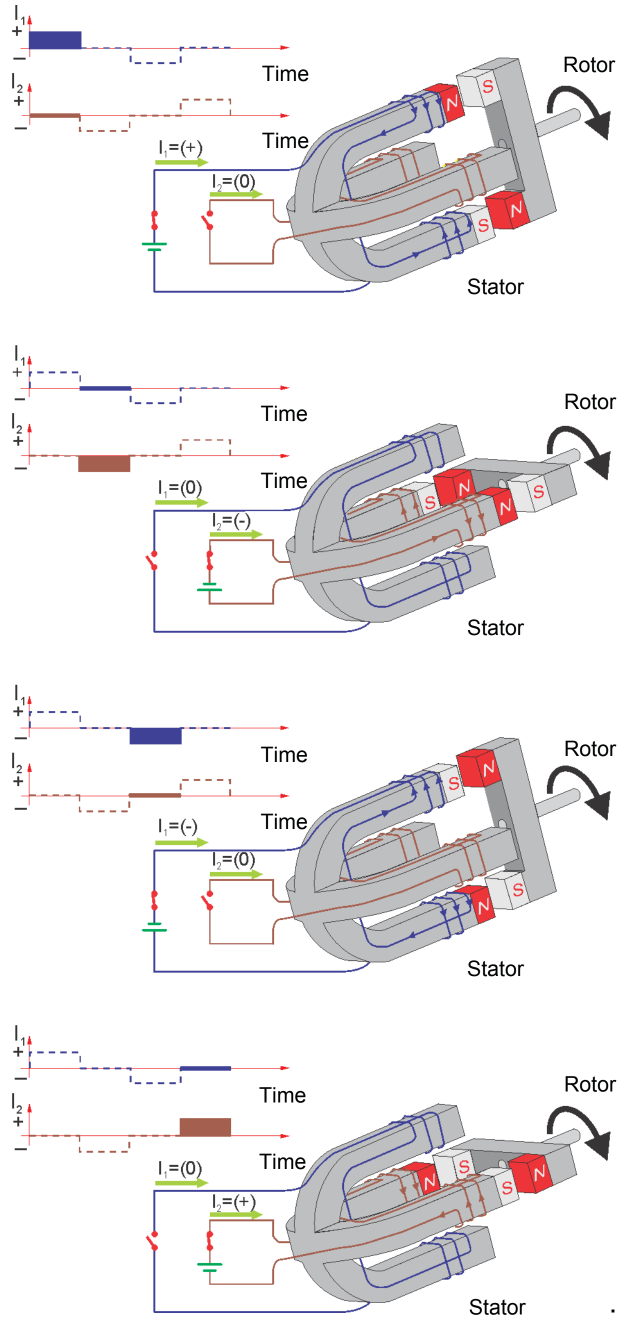


Figure 2. Stepper motor.

Stepper motor

Stepper motors are electric motors for which a single rotation is divided into many intermediate positions or steps. Knowing the number of steps accomplished by the motor and the angle pertaining to one step allows control of the motor position without any feedback mechanism. Figure 2 shows a basic stepper motor in each of its four steps.

To understand how a stepper motor is forced to move, consider the rotor (moving part of the motor) of the stepper motor as a magnet with a north and a south pole. The windings in the stator (fixed part of the motor) are electromagnets that can change polarity to modify the orientation of the resulting magnetic field. Upon a change in the magnetic field orientation, the rotor is forced to realign, causing the motor shaft to rotate. The stepper motors from the Bottling-Process Training System contain more magnets than in this example, providing 200 different steps. Note that even more precise control can be accomplished through the stepper motor drive software by subdividing each step into microsteps.

Figure 3 shows the control diagram of a stepper motor. This system performs open-loop control because no feedback is sent to the controller. For this reason, if the motor misses a step (e.g. the motor torque is too low), there is no means for the controller to sense that an error has occurred.

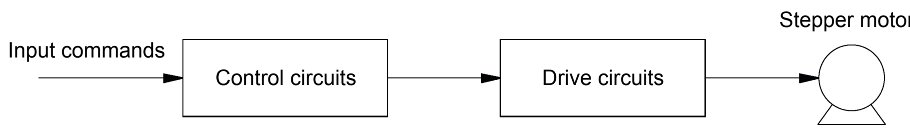


Figure 3. Open-loop control of a stepper motor System.

Pneumatic valve and cylinder

A common way to exert pressure on a bottle cap in the food industry is to use pneumatic equipment. An example is depicted in Figure 4, where wine bottles are capped using a pneumatic cylinder.

The Bottling-Process Training System uses a pneumatic cylinder to secure the lids on the bottles. The piston moves up or down the cylinder depending on the state of the directional control valve supplied with the system.

Figure 4. Bottle capping.

The solenoid-operated valve uses low-voltage control signals to energize a solenoid coil. The electric current flowing through the solenoid coil produces a magnetic field that moves a plunger. Moving the plunger opens a flow path and allows the pilot pressure to act on the valve spool. When the coil is not actuated, the plunger returns to its original position because of a spring located inside the valve. This principle is illustrated in Figure 5.

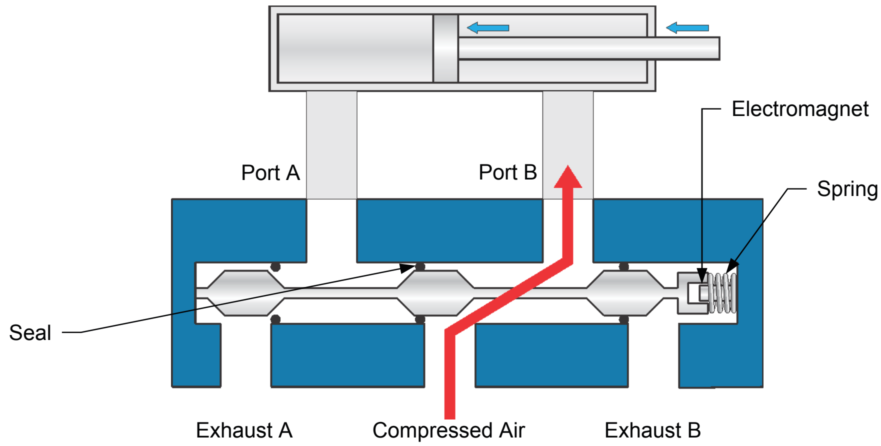


Figure 5. Directional valve operation.

Bottling-Process Training System

The Bottling-Process Training System is made of four modules, apart from the Storage/Work Surface (Model 6309):

- DC Power Supply Drive – Stepper Motor (P/N 3206)
- Dual Stepper Motor Drive (P/N 3208)
- Bottling-Process Module (P/N 3296)
- Directional Valve, Single Solenoid (P/N 6424)

Figure 6 shows the Stepper Motor DC Power Supply. Either one of the two power connectors can be used to provide electrical power to the Stepper Motor Drive.

1. Power Cord.
2. Reset Button.
3. ON/OFF Switch.
4. Stepper Motor Drive Power Connectors.

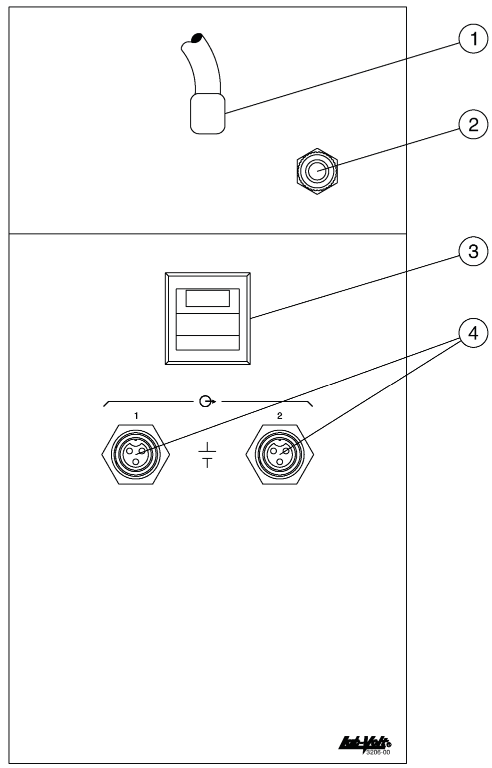


Figure 6. Stepper Motor DC Power Supply, Model 3206.

Figure 7 shows the dual stepper motor drive. This drive is used to control the operation of both stepper motors of the bottling process. It presents four digital inputs, two analog inputs, and one output for feedback. The drive is supplied with a communication cable and software (eXposition™) permitting drive programming.

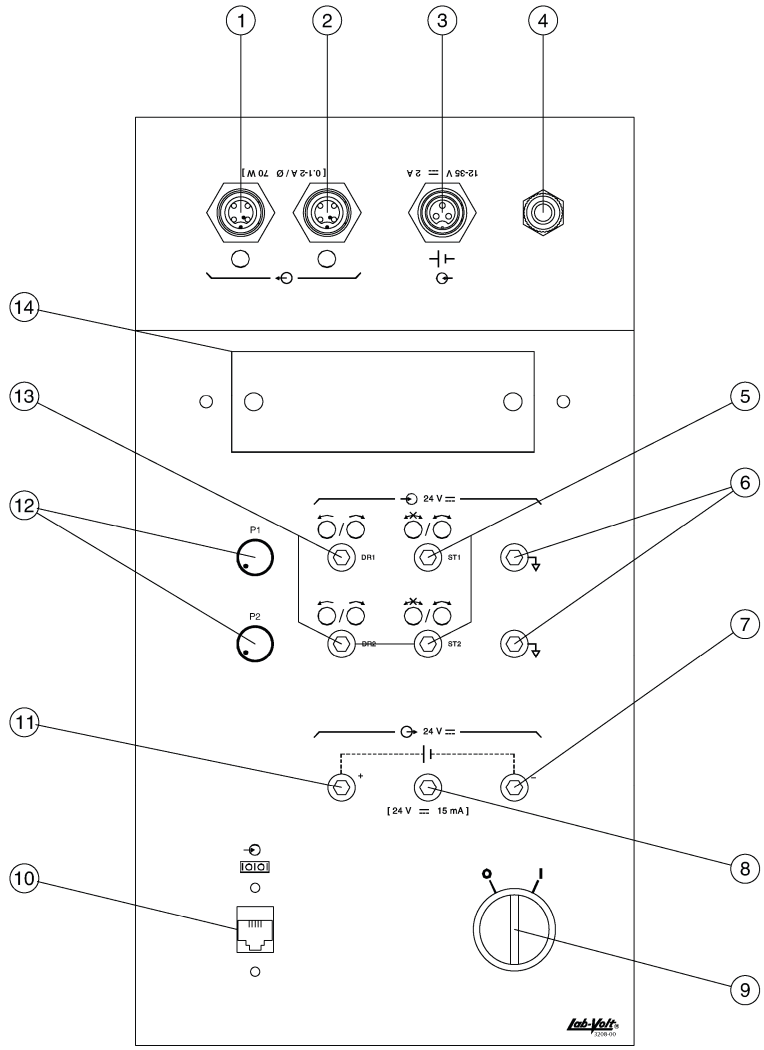


Figure 7. Dual Stepper Motor Drive, Model 3208.

1. Motor 2 Power Connector
2. Motor 1 Power Connector
3. Drive Power Input Terminal
4. Reset Button
5. Step/Run Terminals
6. Input Common Terminals
7. Output Common Terminal
8. Output Terminal
9. ON/OFF Rotary Switch
10. Communication Port
11. Output Power (+24 V) Terminal.
12. Analog Input Potentiometers
13. Direction Terminals
14. Fault Panel

Figure 8 shows the Bottling-Process Module. This module uses two stepper motors to rotate empty bottles and places a lid on them. It uses a pneumatic cylinder to fix the lids on the bottles. A limit switch and an inductive sensor are also included for synchronization.

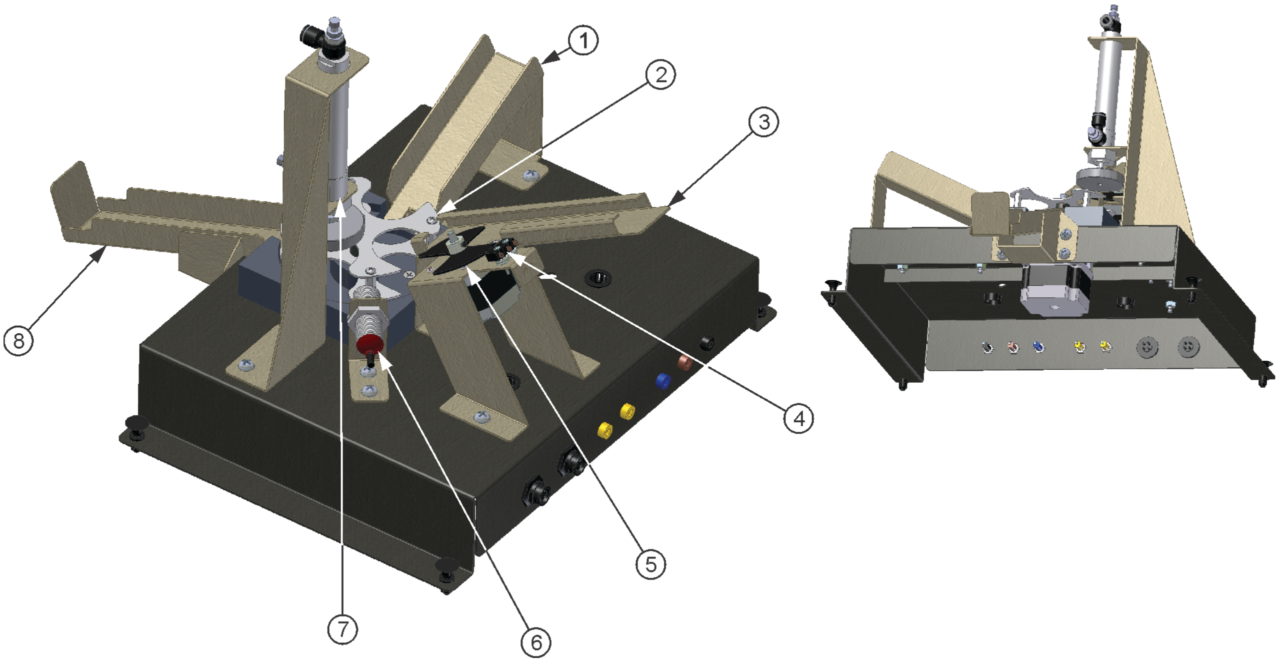


Figure 8. Bottling-Process Module, Model 3296.

1. New Bottles Distributor.
2. Rotary Blades Driven by Stepper Motor 1.
3. Cap Distributor.
4. Normally Open Limit Switch.
5. Rotary Blade Driven by Stepper Motor 2.
6. Inductive Sensor.
7. Pneumatic Cylinder.
8. Bottle receptacle.

Figure 9 shows the Single Solenoid-Actuated Directional Control Valve. It consists of a four-way, two-position, single-solenoid operated, spring-return directional control valve.

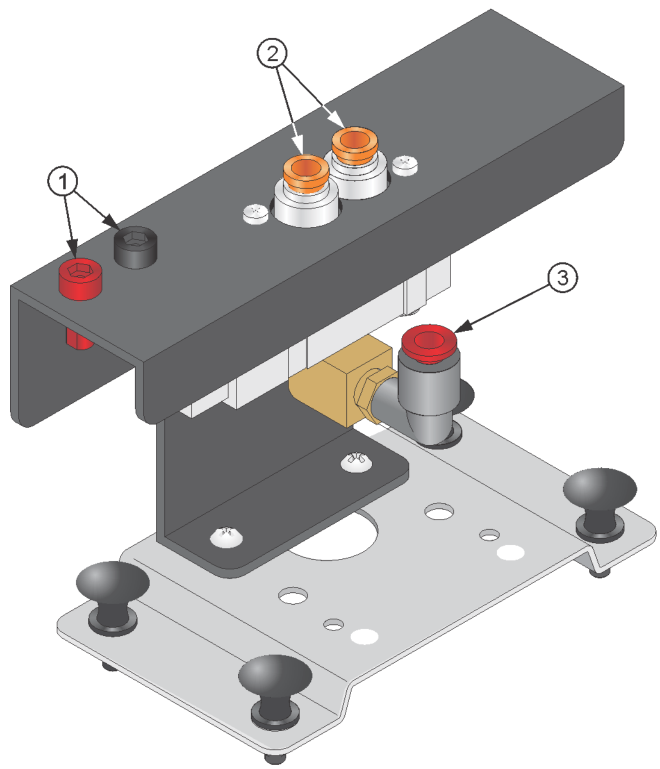


Figure 9. Single Solenoid-Actuated Directional Control Valve, Model 6424.

1. 24 V dc Valve Terminals.
2. Valve Pressure Ports.
3. Pressure Port.

The system control section operates with low voltage signals (24 V dc). The PLC is programmed and monitored using a computer running a ladder programming software.

Stepper motor drive software

The *eXposition*™ software accompanying the Stepper Motor Drive provides means to take full advantage of the system's stepper motors. Figure 10 shows the software's main screen.

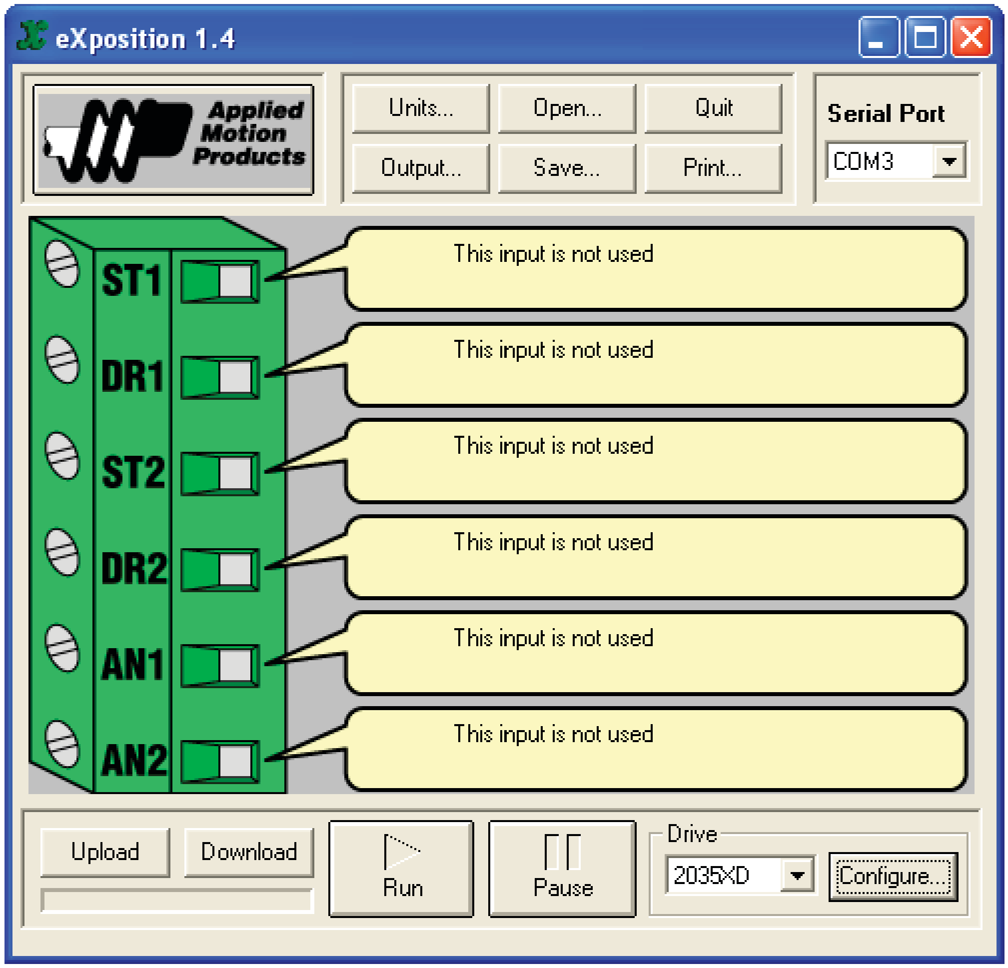


Figure 10. Stepper motor drive software main screen.

The first step while opening the program is to configure the drive. Pressing the button at the bottom right of the main screen brings you the window of Figure 11. Press the “Scan Drive” button if your drive is connected to the PC. Alternatively, you can select the 2035XD drive from the list. You can also change the drive current if necessary.

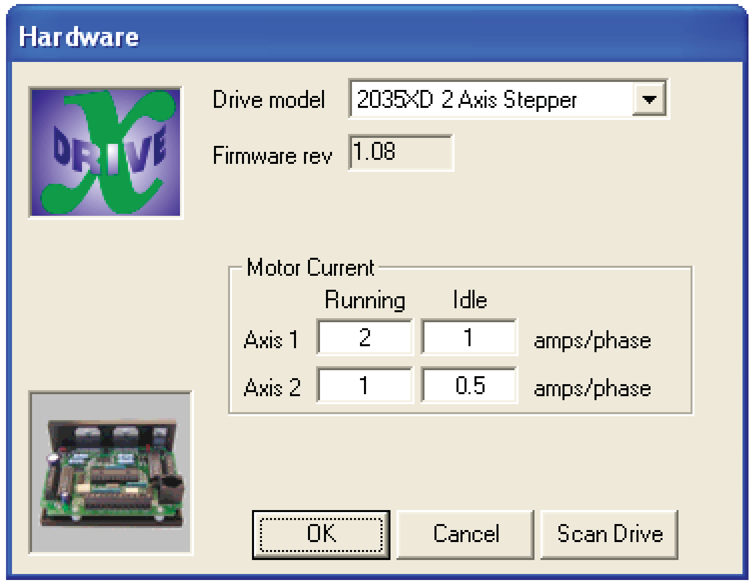


Figure 11. Hardware configuration screen.

When you click on the ST1 or ST2 cartoon bubble on the main screen, the dialog box of Figure 12 appears. It displays the two different modes under which the Dual Stepper Motor Drive, Model 3208 can operate the motors.

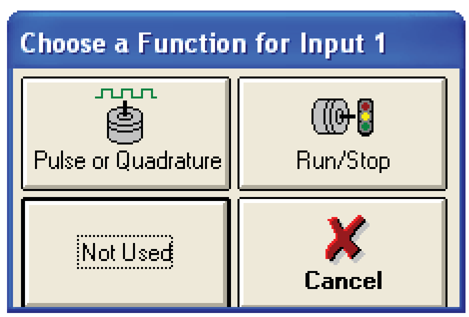


Figure 12. Hardware configuration screen.

– Run/Stop Mode. Figure 13 shows the screen pertaining to this mode. The motor will be active if input ST is actuated. Input DR will make the motor turn in one direction or the other, depending on its state. The motor speed is proportional to the analog input if the checkbox is selected.

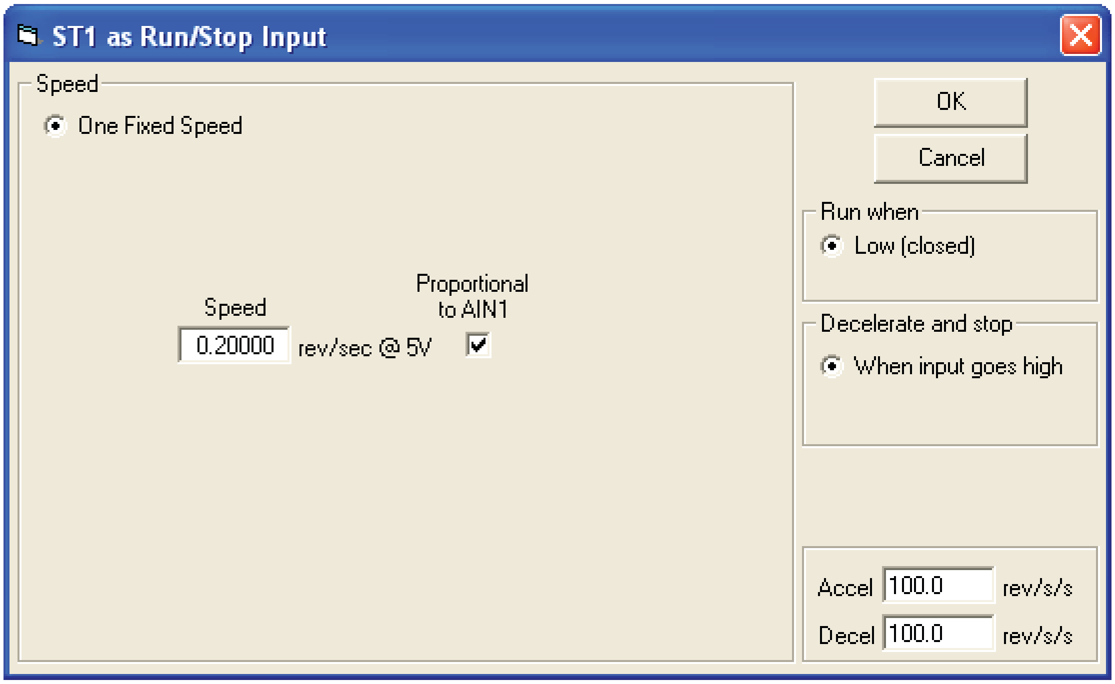


Figure 13. Run/Stop screen.

– A train of pulses is required to input ST to determine speed. A signal is required at input DR to change motor rotation direction. You can choose the number of steps per motor revolution (up to 50800).

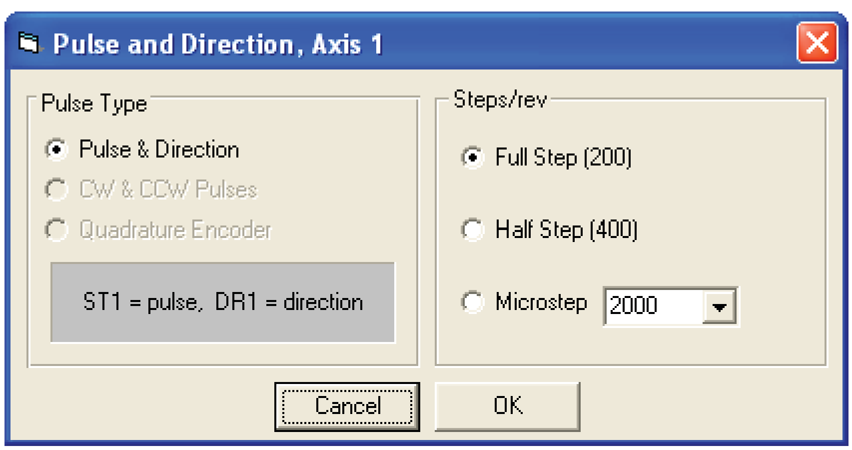


Figure 14. Pulse and Direction screen.

Familiarization with the Bottling-Process Training System

OBJECTIVE

- Test the operation of some basic system components.

PROCEDURE

CAUTION

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

1. Connect the Bottling-Process Training System according to Figure 15. All toggle switches must be turned off (down position). No bottle or cap must be present in the system at this time.

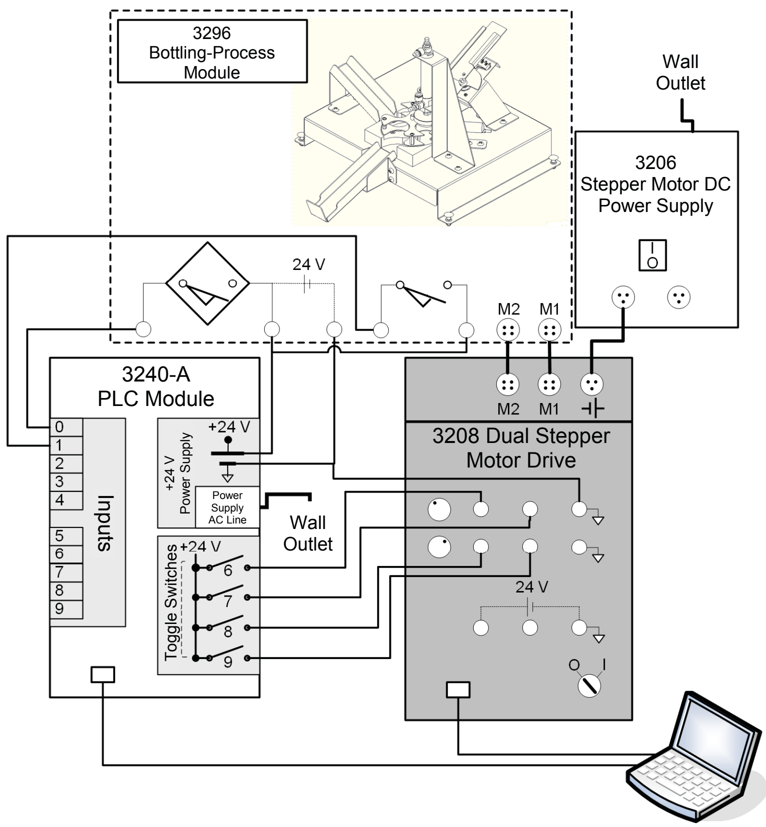


Figure 15. Station control valve test circuit.

Table 1. Job Sheet 1 PLC connections (switches).

PLC module Switch	Connected to
Switch 6 (Toggle)	Dual Drive DR1
Switch 7 (Toggle)	Dual Drive ST1
Switch 8 (Toggle)	Dual Drive DR2
Switch 9 (Toggle)	Dual Drive ST2

Table 2. Job Sheet 1 PLC connections.

PLC module Port	Connected to
Input I/0	Proximity Detector
Input I/1	Limit Switch

2. Start the eXposition drive software on your computer. Configure the serial port and the drive.

If no serial port is available on the computer, a USB to serial adapter such as P/N 34879 can be used.

Turntable operation

3. Program the drive according to Figure 16. Note that the analog inputs (AIN1 and AIN2) are not used.

Do not forget to download the program to the drive and press the Run button to make it effective.

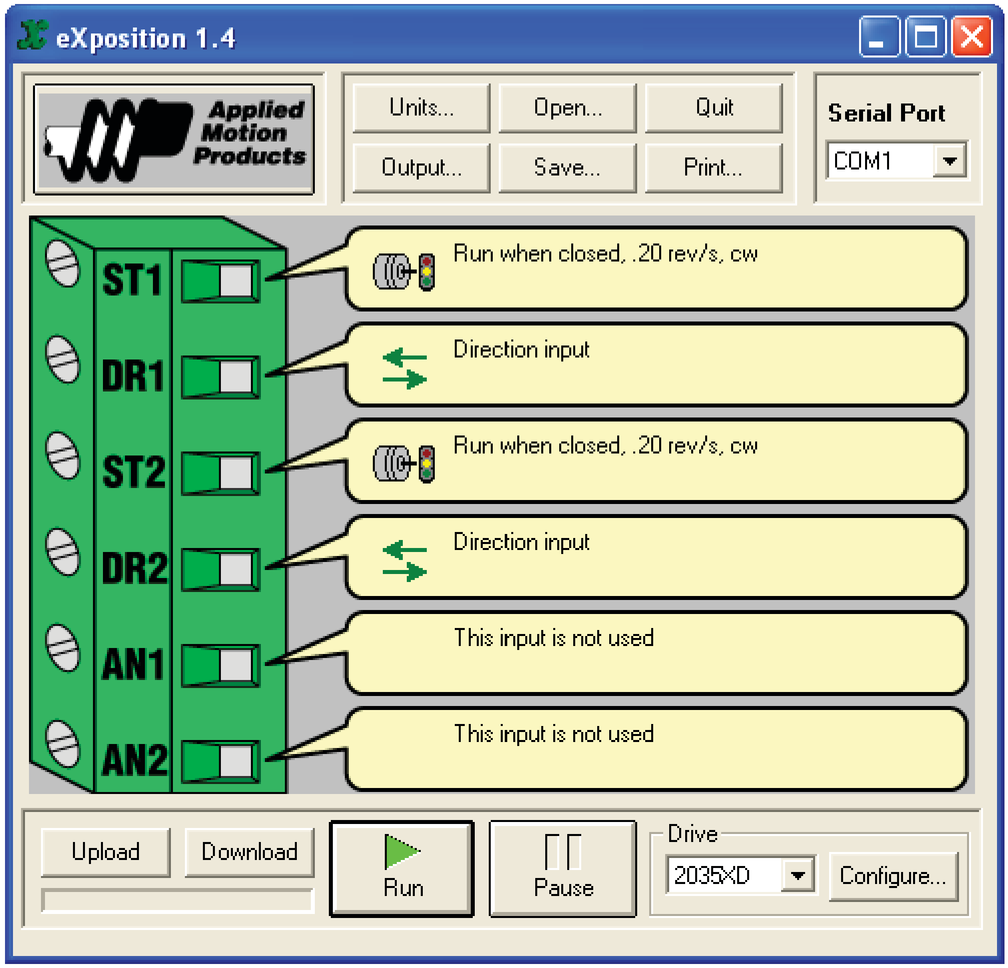


Figure 16. Fixed speed drive program.

4. Actuate drive input ST1 (step/run1) to jog the motor 1 (turntable). In which direction do the blades turn?

   ❑ Clockwise ❑ Counterclockwise

   Counterclockwise.

   Turn off drive input ST1 and turn on drive input DR1. Turn drive input ST1 back on. In which direction do the blades turn?

   ❑ Clockwise ❑ Counterclockwise

   Clockwise.

In which direction should the blades turn to direct the bottles correctly?

❑ Clockwise ❑ Counterclockwise

Clockwise.

5. Does the proximity sensor detect all metal spacers linking the two rotating blades?

❑ Yes ❑ No

Yes

You can see the proximity sensor state by observing the LED on the sensor or the state of input I/0 on your PLC. Alternately, you can use a voltmeter to monitor when the limit switch closed.

Turn off all drive inputs. If the answer to the preceding question is no, readjust the position of the proximity sensor until every metal spacer is detected.

Cap distributor operation

6. Actuate drive input ST2 (step/run1) to jog the motor 2 (cap distributor). In which direction does the blade turn?

❑ Clockwise ❑ Counterclockwise

Counterclockwise.

Turn off drive input ST2 and turn on drive input DR2. Turn drive input ST2 back on. In which direction do the blades turn?

❑ Clockwise ❑ Counterclockwise

Clockwise

In which direction should the blades turn to feed the caps correctly?

❑ Clockwise ❑ Counterclockwise

Counterclockwise.

7. Does the limit switch detect every half-turn rotation of the blade?

❑ Yes ❑ No

Yes

Depress the manual override control located on top of the double solenoid valve. Does this make the cylinder rod extend and retract?

❑ Yes ❑ No

Yes

You can see the limit switch state by observing the state of input I/1 on your PLC. Alternately, you can use a voltmeter to monitor when the limit switch closes.

Turn off all drive inputs. If the answer to the preceding question is no, readjust the position of the limit switch until every half-turn rotation is detected.

Speed control

8. Program the drive according to Figure 17. Note that the analog inputs (AIN1 and AIN2) are now used and the nominal speed rotation has changed.

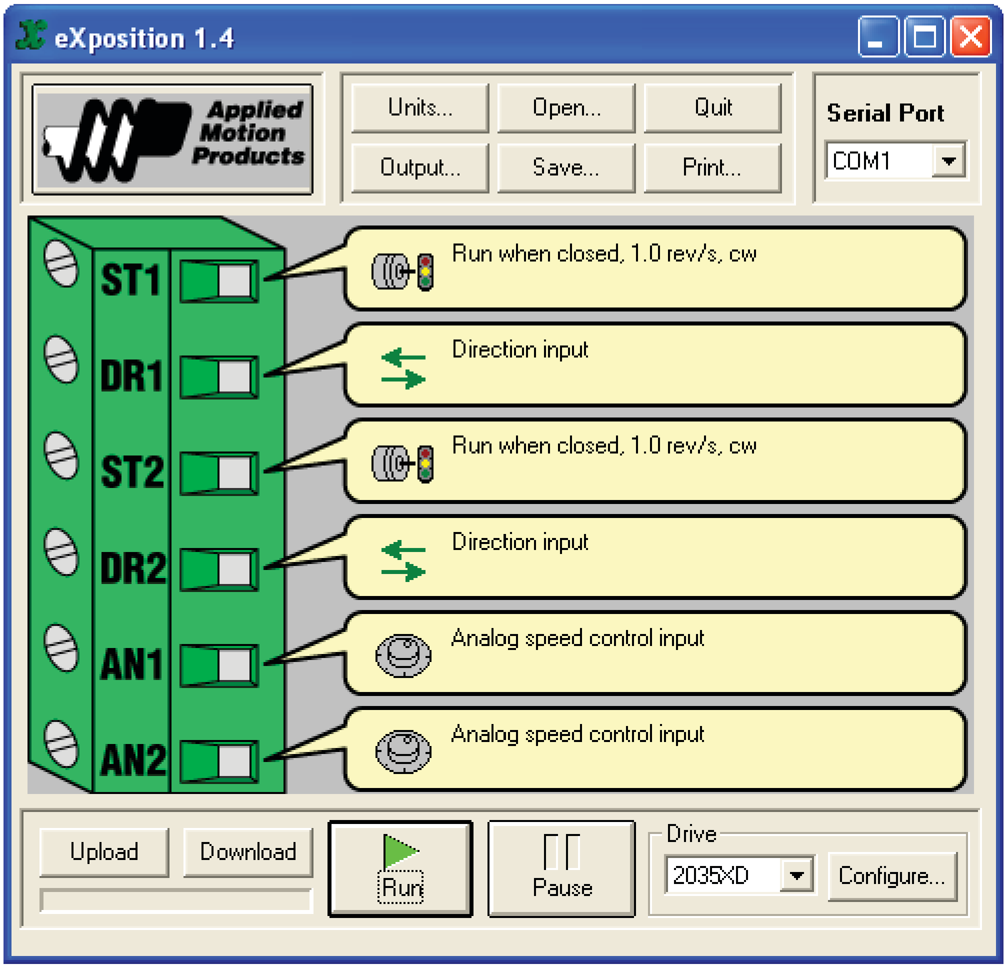


Figure 17. Adjustable speed drive program.

Test the new drive program with the help of the 4 toggle switches and the analog inputs.

9. Turn off all drive inputs. Try to adjust manually the speed of the two stepper motors so that a cap can be dropped on every bottle without stopping the process. Now position open bottles and caps in the bottling process and test your setup. Stop the motors and repeat if necessary. Do you think it is a reliable means of capping the bottles?

❑ Yes ❑ No

Later in this manual, the PLC program will stop motor 1 while the cap is dropped.

No

Pneumatic cylinder control

10. Connect PLC toggle switch 10 to the Directional Valve positive (+) terminal and the PLC negative (-) terminal to the Directional Valve negative (-) terminal.

11. Connect the tubing between the pneumatic cylinder, the directional valve and the pressurized air source according to Figure 18.

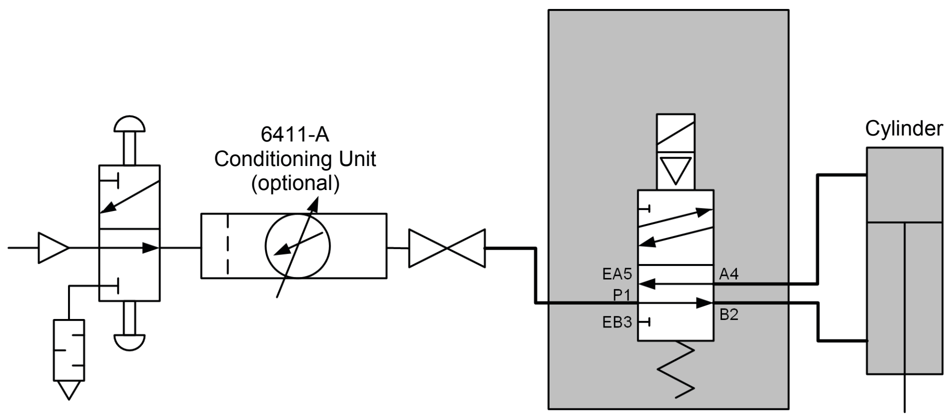


Figure 18. Pneumatic connections of the Bottling Process application.

To avoid air leaking from the connectors, make sure that plastic tubes are cut clean and inserted deep enough into the connectors.

Plastic tubes are removed by pressing the release ring towards the body of the connector before pulling out the tubing (See Figure 19).

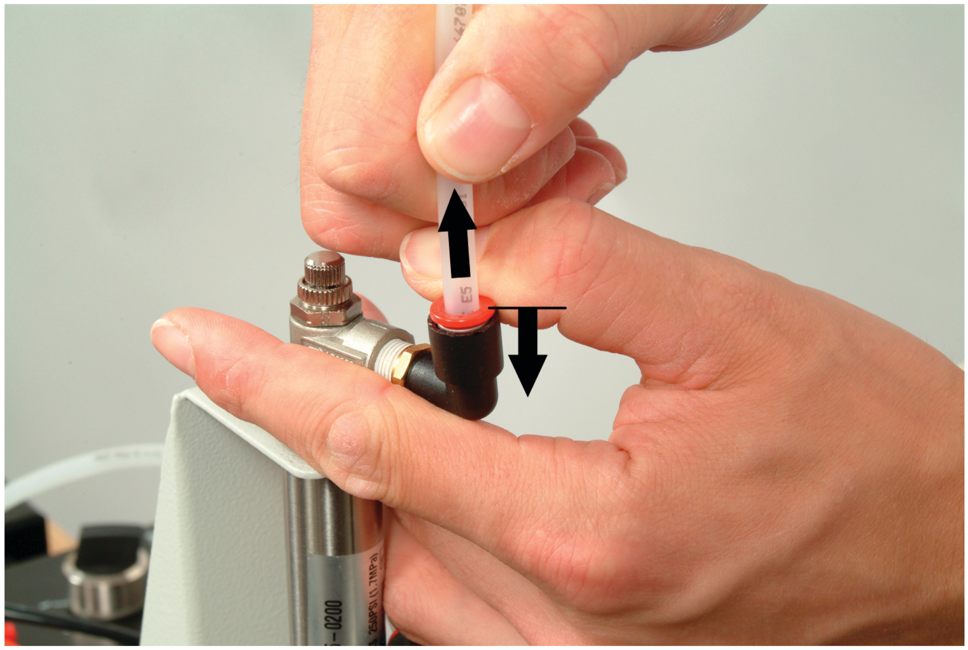


Figure 19. Plastic tubing removal.

Incoming air pressure should be set between 80 and 100 PSI.

12. Using the toggle switches controlling the motor 1, position a bottle with a loose cap on under the pneumatic cylinder.

The Proximity detector LED should be lit in this position because a metal spacer is located in front of the proximity sensor.

Open the compressed air source. Actuate the directional valve solenoid with the help of the toggle switch 10. Does the pneumatic cylinder extend?

❑ Yes ❑ No

Yes

De-energize the directional valve solenoid. Does the pneumatic cylinder retract?

❑ Yes ❑ No

Yes

Was the bottle capped correctly?

❑ Yes ❑ No

Yes

13. Demonstrate the operation of the Bottling-Process Training System to your instructor.

14. Shut off the compressed air source.

15. Disconnect and store all leads and components.

Name: ______________________ Date: ______________

Instructor's approval: ________________________________