Refrigeration and HVAC

Refrigeration Capstone Project

Course Sample

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Safety and Common Symbols

The following safety and common symbols may be used in this course 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 danger. Consult the relevant user documentation.
	Caution, risk of electric shock.
	Caution, lifting hazard.
	Caution, hot surface.
	Caution, risk of fire.
	Caution, risk of explosion.

Symbol	Description
	Caution, belt drive entanglement hazard.
	Caution, chain drive entanglement hazard.
	Caution, gear entanglement hazard.
	Caution, hand crushing hazard.
	Static sensitive contents. Observe precautions for handling electrostatic discharge sensitive devices.
	Notice, non-ionizing radiation.
	Consult the relevant user documentation.
	Radio Equipment Directive (RED) geographical restrictions – consult the relevant user documentation.
	Direct current.
	Alternating current.
	Both direct and alternating current.

Symbol	Description
	Three-phase alternating current.
	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.

Preface

The Refrigeration Capstone Project comprises a hands-on workstation designed specifically for the Refrigeration and Air Conditioning 2017 WorldSkills event. In this world-renowned competition, contestants from a multitude of countries carried out a challenging and motivating refrigeration project on the workstation. Of the participants, two competitors tied for the first place, performing the tasks demanded with more talent, meticulousness, imagination, and speed than the others.

Based on the positive feedback from experts, Festo Didactic decided to make the Refrigeration Capstone Project available to institutions training skilled refrigeration technicians. The purpose of the project's workstation is to provide future refrigeration technicians a challenging project to sharpen and master their already solid set of skills.

We hope the Refrigeration Capstone Project helps student consolidate their skills in refrigeration and becomes the start of a long and distinguished career in that field.

Figure 1. Student performing the wiring installation.[1]

Figure 2. Student brazing a joint.[2]

Figure 3. Student working in the electrical panel.[3]

[1] Courtesy of WorldSkills.
[2] Courtesy of WorldSkills.
[3] Courtesy of WorldSkills.

We invite readers to send us their tips, feedback, and suggestions for improving the course.

Please send these to

mailto:services.didactic@festo.com

The authors and Festo Didactic look forward to your comments.

About This Course

Course objectives

When you have completed this course, you will be able to do the following:

- Set up and commission a refrigeration system that produces ice in a basin.
- Follow both guided and unguided procedures to perform the piping and electrical wiring required to commission the system.
- Braze pipes and connections according to piping diagrams.
- Install and commission the different components in the system, such as a compressor, a condenser, pressure controls, temperature controllers, and other common refrigeration components.
- Test the system for leaks and troubleshoot those leaks if necessary.
- Produce a commissioning report to make sure the system functions according to specifications.

Safety considerations

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

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

Make sure you wear 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.

Reference material

During system setup and commissioning, refer to the flow, mechanical, and electrical diagrams and drawings provided with the project. Some are also reproduced in this course for ease of viewing.

Also, when you unbox components, such as the compressor, suction accumulator, liquid receiver, valves, and regulators, it is highly recommended to read the manufacturer's documentation and to keep it for future reference.

Finally, it is also recommended to consult the videos provided in this course. These videos show a technician performing key tasks necessary to setup and commission the system. Although students performing this course should be familiar with all techniques showcased in the videos, they can be useful by providing advice and ideas on how to perform the manipulations in this course.

Prerequisite

A solid grasp of the fundamental concepts in the technical fields of refrigeration and electricity, as well as the related practical skills, is a prerequisite to this course. It is assumed that you have a general understanding of these concepts:

- Refrigeration field
    - Principles of physics associated to refrigeration, such as heat and heat transfer, molecules and energy, as well as pressures and temperatures.
    - Refrigeration systems and their basic components, such as compressors, evaporators, condensers, and metering devices.
    - Control devices, such as pressure controllers, thermostats, and solenoid valves.

- Electrical field
    - Notions of current, voltage, and resistance.
    - Electrical measurement using a multimeter.

System of units

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

To the Instructor

You will find in this Instructor Guide all the elements included in the Student Manual together with 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.

Time requirements

At the beginning of each section in this manual, you will find an indication of the time required by an average student to perform the section. It is important to note that this time indication is for reference purposes only. The actual time required by students may vary significantly from one class to another, and from one student to another.

To prevent inconsistencies in the times required to complete sections, it is recommended that the instructor performs the tasks in the section beforehand to obtain a general idea of the time required to complete the section. The instructor can then better estimate the time required for his or her class to perform the tasks.

Sample

Extracted from

Instructor Guide

Guided Installation of the Piping and Components

Part 1 - Bending and Assembly of the Coils

Setup and preliminary requirements

Safety procedures

Before performing this procedure, make sure to complete the following checklist:

- ☐ You are wearing safety glasses, safety shoes, and safety gloves.
- ☐ You are not wearing anything that might get caught, such as a tie, jewelry, or loose clothing.
- ☐ Your sleeves are rolled up.
- ☐ If your hair is long, tie it out of the way.
- ☐ The working area is clean and free of spilled oil or refrigerant.
- ☐ The working area is well ventilated.
- ☐ The floor is not wet. Furthermore, the risks of tripping hazards on the floor due to wires, cord lines, cables or other such equipment are minimized.

System setup

24 min.

Competency

- *Be able to perform a lockout/tagout procedure.*

At the beginning of this procedure, the system should be set up as shown in the following figure, which corresponds to the factory default setup. In particular, note that:

- The system's frame and panels are fixed in place.
- No refrigeration component (e.g., compressor, suction accumulator, liquid receiver, condenser, etc.) is installed.
- The electrical panel is mounted on the system. Some connections are already present in the electrical panel, but all terminals required for

connection to the components that will be installed on the system are free.

Figure 6. System at the beginning of Exercise 1.

Lockout/tagout procedure

Before working with the system, it is essential to ensure your safety and that of your teammates by performing the following lockout/tagout procedure:

- Make sure the power light on the control panel is turned off. If not, set the main switch to the O (off) position.
- Make sure the compressor, condenser fan, and heat recovery lights are turned off.
- Write your name on a tag.
- Install the lockout and tagout devices on the main switch.
- Lock the lockout and tagout devices with a padlock, as shown in the following figure.
- Ask each teammate to install their own padlock on the lockout device.

Figure 7. Lockout/tagout setup on the main switch.

When you have finished working on the system, remove the tagout device bearing your name and its padlock from the lockout device.

Note regarding the components

When performing the project, it is highly recommended to keep the components included in the system in an orderly fashion. For example, the different bags of screws and fasteners are separated according to the specific component(s) they are designed for. Do not mix them together.

Also, when students unbox components, such as the compressor, suction accumulator, liquid receiver, valves, and regulators, it is highly recommended to read the manufacturer's documentation and keep it for future reference.

	**⚠ CAUTION**
	Any improper use of the components included in the system could cause damage to the equipment or injuries.

System flow diagram

Before performing the Refrigeration Capstone Project, all students must study and understand the flow diagram of the system, as shown in the following figure. If some components or processes are unclear, it is the students' responsibility to research them before going further in this procedure.

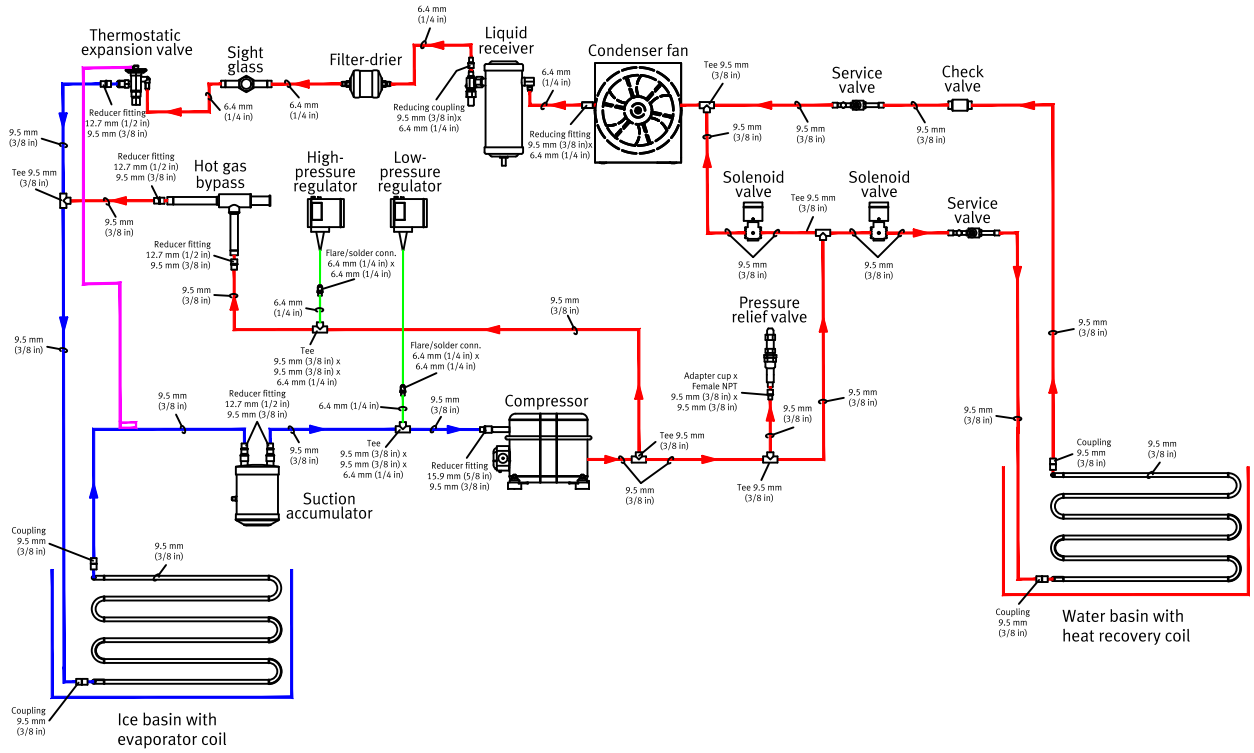

Figure 8. System flow diagram.

Evaporator coil

60 min.

Competencies

- *Be able to use a pipe bender, a pipe cutter, and a pipe reamer to bend piping.*
- *Be able to bend a heat exchanger coil comprising five U-bends in a single row according to a piping diagram.*

In this subsection, you will bend the evaporator coil (left heat exchanger coil in the system). You will then mount the coil in its brackets.

1. Locate and retrieve the following components and tools:
   - 9,5 mm (3/8 in) piping

     A piping length of about 344 cm (135 in) is required for the evaporator coil.

   - Two mounting brackets for the evaporator coil. These brackets can accommodate a single row of piping (five U-bends).
   - Pipe bender

- Pipe cutter
- Pipe reamer
- Ruler or tape measure and marker

2. Using the pipe bender, bend the piping to obtain the coil shown in the diagram of the following figure. When you cut the pipe, make sure to also ream it to remove any significant burrs.

If necessary, refer to the evaporator coil piping diagram included in the plans for the project.

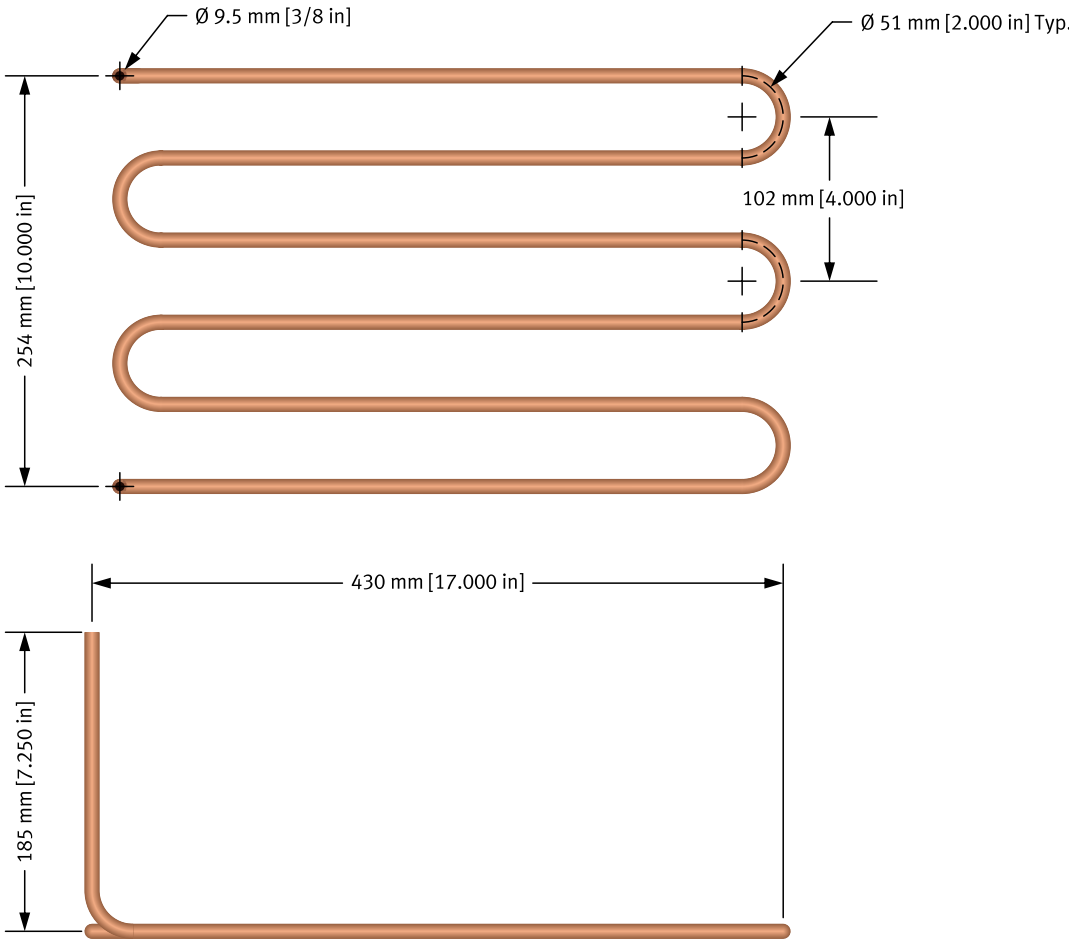

Figure 9. Piping diagram of the evaporator coil.

Figure 10. Technician bending piping.

For more information on how to bend piping, consult the following video.

Technician bending parts of the evaporator coil

https://ip.festo-didactic.com/FDCAQRCodes/qrcode0048.html

3. Insert the evaporator coil in the mounting brackets designed for this coil, as shown in the following figure. If it does not fit, check and correct your work.

Figure 11. Technician assembling the evaporator coil.

For more information on how to finalize the assembly of the evaporator coil, you can consult the following video.

Technician finalizing the assembly of the evaporator coil

https://ip.festo-didactic.com/FDCAQRCodes/qrcode0049.html

4. The following figure shows a representation of the assembled evaporator coil with its mounting brackets.

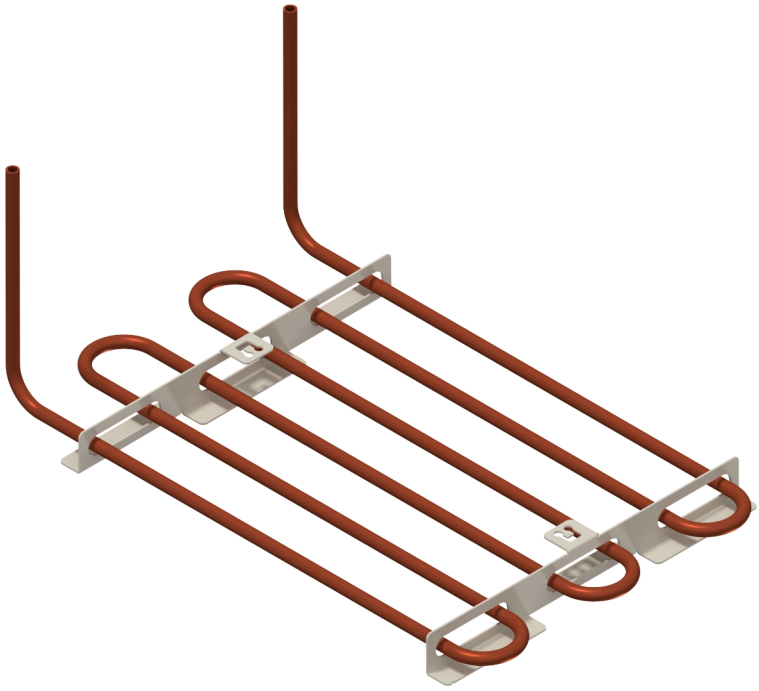

Figure 12. Assembled evaporator coil with its mounting brackets.

5. Place the evaporator coil in the ice basin, as shown in the following figure. Make sure the input and output pipes of the coil face the middle portion of the system.

Place caps on the ends of the coil when you're not working on it. This prevents contaminants from entering the coil.

Figure 13. Evaporator coil in the ice basin.

Heat recovery coil

120 min.

Competencies

- *Be able to use a pipe bender, a pipe cutter, and a pipe reamer to bend piping.*
- *Be able to bend a heat exchanger coil comprising seventeen U-bends in three rows according to a piping diagram.*

In this subsection, you will bend the heat recovery coil (right heat exchanger coil in the system). You will then mount the coil in its brackets.

6. Locate and retrieve the following components and tools:

- 9.5 mm (3/8 in) piping

  A piping length of about 962 cm (379 in) is required for the heat recovery coil.

- Two mounting brackets for the heat recovery coil. These brackets can accommodate three rows of piping (seventeen U-bends).
- Pipe bender
- Pipe cutter
- Pipe reamer
- Ruler or tape measure and marker

7. Using the pipe bender, bend the piping to obtain the coil shown in the diagram of the following figure. When you cut the pipe, make sure to also ream it to remove any significant burrs.

If necessary, refer to the heat recovery coil piping diagram included in the plans for the project.

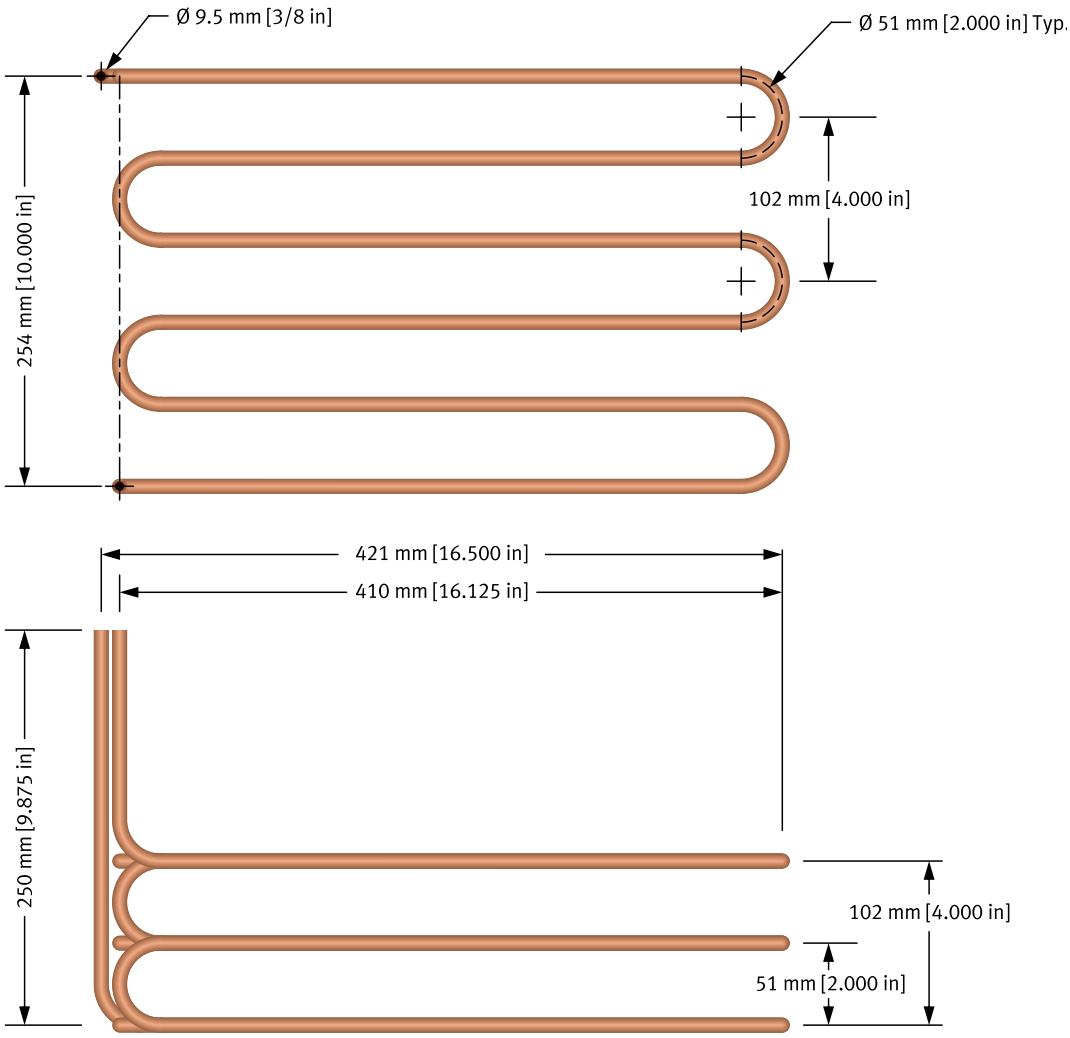

Figure 14. Piping diagram of the heat recovery coil.

8. Insert the heat recovery coil in the mounting brackets designed for this coil. If it does not fit, check and correct your work. The following figure shows a representation of the assembled heat recovery coil with its mounting brackets.

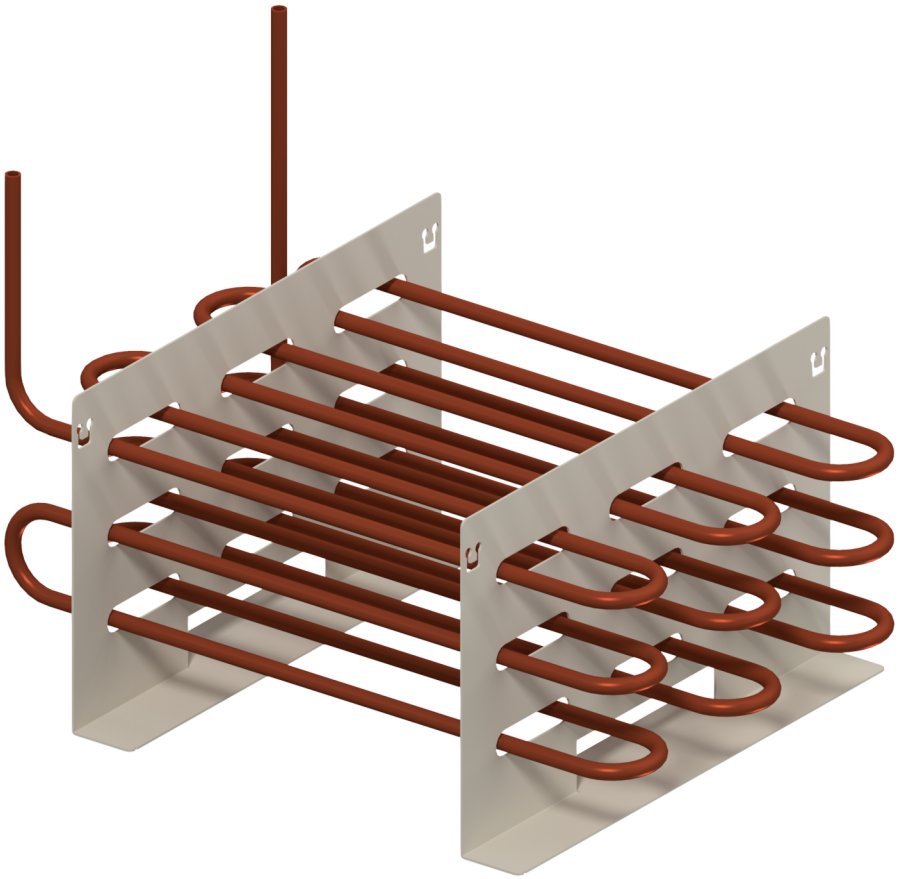

Figure 15. Assembled heat recovery coil with its mounting brackets.

9. Place the heat recovery coil in the water basin. Make sure the input and output pipes of the coil face the middle portion of the system.

Place caps on the ends of the coil when you're not working on it. This prevents contaminants from entering the coil.

Part 2 - Assembly and Brazing of the Heat Recovery Circuit

Assembly of the heat recovery circuit

60 min.

Competencies

- *Be able to use a pipe bender, a pipe cutter, and a pipe reamer to bend and assemble piping.*
- *Be able to assemble a heat recovery circuit comprising solenoid valves, ball valves, and a check valve according to a piping diagram.*

In this section, you will assemble the heat recovery circuit that makes the connections between the heat recovery coil and the condenser.

1. Locate and retrieve the following components and tools:

   - 3/8" piping and fittings

     About 449 cm (177 in) of piping is required for the heat recovery circuit.

   - Two ball valves with a Schrader valve
   - Two solenoid valves
   - Check valve
   - Pipe bender
   - Pipe cutter
   - Pipe reamer
   - Ruler or tape measure and marker

2. Using the pipe bender and the pipe cutter, assemble the input branch of the heat recovery circuit, according to the diagram shown in the following figure. This branch contains a ball valve with a Schrader valve (for connection to a manometer) and two solenoid valves. When you cut the pipe, make sure to also ream it to remove any significant burrs.

   Make sure to connect the solenoid valves and ball valve with the correct orientation, as indicated in the diagram.

   If necessary, refer to the refrigeration flow diagram and heat recovery circuit diagram included in the plans for the project.

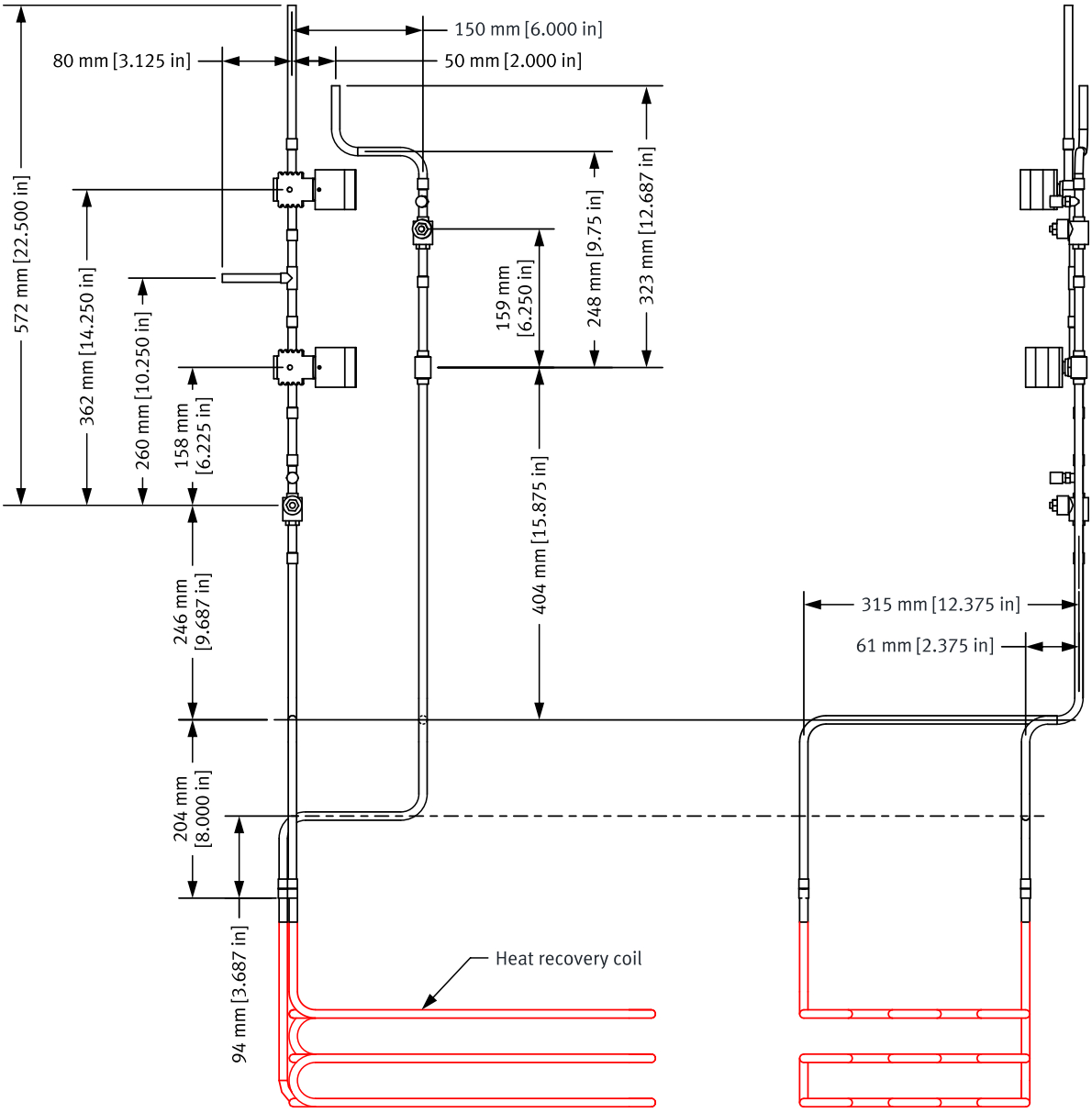

Figure 16. Piping diagram of the heat recovery circuit.

3. Using the pipe bender and the pipe cutter, assemble the output branch of the heat recovery circuit, according to the diagram shown in the previous figure. This branch contains a check valve and a ball valve with a Schrader valve (for connection to a manometer). When you cut the pipe, make sure to also ream it to remove any significant burrs.

Before brazing, make sure the orientation of the ball valves and check valve is correct, as indicated in the diagram.

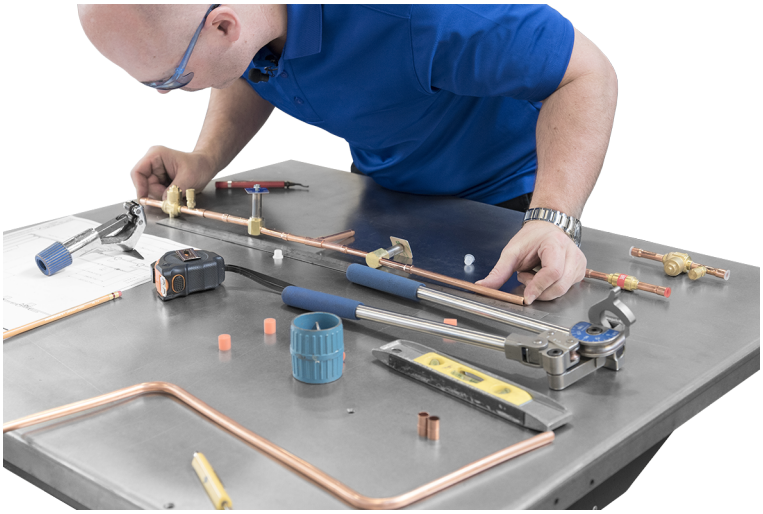

Figure 17. Technician assembling the heat recovery circuit.

For more information on how to cut pipes and assemble the heat recovery circuit, consult the following video.

Technician cutting pipes and assembling the heat recovery circuit

https://ip.festo-didactic.com/FDCAQRCodes/qrcode0050.html

4. The following figure shows assembled heat recovery circuit. Do not attach the circuit to the heat recovery coil for the moment.

Figure 18. Assembled heat recovery circuit.

Brazing of the heat recovery circuit

90 min.

Competency

- *Be able to use a brazing torch and Sil-Fos brazing alloy to braze the joints of a copper piping circuit.*

In this section, you will braze the piping of the heat recovery circuit you assembled in the previous section.

5. Locate and retrieve the following components and tools:
   - Two branches of the heat recovery circuit
   - Brazing torch with a supply of oxygen and a supply of acetylene
   - Sil-Fos brazing alloy
   - Spacers to raise the piping above the work surface while brazing
   - Wet cloths or wipes
   - Two solenoid valve magnet tools
   - A supply of nitrogen
   - Fire extinguisher

6. On each ball valve, remove the Schrader valve before brazing. This is necessary to prevent the rubber material in the valve from melting during brazing.

For more information on how to remove the Schrader valve from a ball valve, consult the following video.

Technician removing the Schrader valve from a ball valve

https://ip.festo-didactic.com/FDCAQRCodes/qrcode0051.html

7. Using wet cloths or wipes, cover the valves on the heat recovery circuit branches. This is necessary to prevent the heat from the brazing torch from damaging the valves.

8. Place both branches of the heat recovery circuit on spacers on the work surface. Make sure the spacers maintain the piping about one inch away from the work surface.

9. Place one solenoid valve magnet tool on each solenoid valve to open the valve and allow air flow in it. To do so, remove the screw and the coil from the valve. Then, install the magnet at the top of the stem. You should hear a click indicating the valve is open. This step is necessary to ensure nitrogen reaches the parts downstream of the valve while brazing.

10. Using the supply of nitrogen, make nitrogen flow from one end of each branch to the other while brazing. This purges the air from each branch.

For more information on how to prepare tubing for brazing, consult the following video.

Technician preparing tubing for brazing

https://ip.festo-didactic.com/FDCAQRCodes/qrcode0052.html

11. Using the brazing torch and Sil-Fos alloy, braze all the joints on the heat recovery circuit piping. Perform this step one branch at a time. While brazing, make sure that nitrogen flows from one end of the branch to the other, to purge all oxygen from the branch and reduce oxidation.

Before brazing, it is recommended to clean all piping to remove oil, grease, and oxide contamination. For this purpose, brush the pipes with a stainless-steel wire brush and a solvent. Finally, remove any particles using a clean, dry cloth.

⚠ WARNING

When brazing, always take care to orient the torch away from you and from flammable objects. Orient the flame away from the valves to avoid damaging them. Furthermore, always use gloves to protect your hands, and make sure a fire extinguisher is at hand in case a fire occurs.

Figure 19. View of the brazing technique.

Figure 20. Technician brazing the heat recovery circuit.

For more information on how to braze a joint, consult the following video.

Technician brazing a joint

https://ip.festo-didactic.com/FDCAQRCodes/qrcode0053.html

Throughout this section, if you make a mistake while brazing, disassemble the brazed joint, as shown in the following video.

Technician disassembling a brazed joint

https://ip.festo-didactic.com/FDCAQRCodes/qrcode0054.html

12. Once both branches of the heat recovery circuit are correctly brazed, insert each branch in the corresponding input and output of the heat recovery coil. Do not braze these components together for the moment.

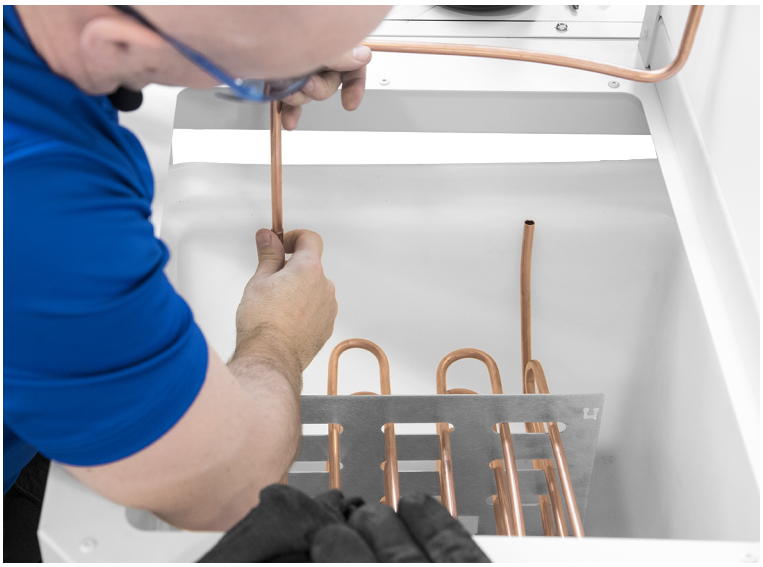

Figure 21. Technician inserting a branch of the heat recovery circuit in a piping of the heat recovery coil.

13. Install spacers to maintain the heat recovery circuit in place on the system, as shown in the following figure.

Figure 22. Technician installing spacers.

14. On each ball valve, put the Schrader valve back in place.

Part 3 - Installation of the Main Components

Installation of the compressor, suction accumulator, and liquid receiver

75 min.

Competencies

- *Be able to drill mounting holes for refrigeration components according to an installation diagram.*
- *Be able to mount a compressor, a suction accumulator, and a liquid receiver on a horizontal plate according to an installation diagram.*

In this section, you will drill mounting holes on the horizontal plate of the system's middle portion. You will then install the compressor, suction accumulator, and liquid receiver on these mounting holes.

1. Locate and retrieve the following components and tools:
   - Compressor
   - Suction accumulator
   - Liquid receiver
   - Screw and fastener kit for the compressor (bag 1)
   - Screw and fastener kit for the suction accumulator and liquid receiver (bag 2)
   - Tools for fastening screws and nuts (e.g., screwdriver, wrench)
   - Drilling tool with bits of appropriate size

2. On the horizontal plate of the middle portion of the system, locate where you will need to drill the mounting holes for the components, according to the diagram shown in the following figure. Place markings on the horizontal plate as required. Make sure not to drill outside the triangle limits of the removable plate.

If necessary, refer to the mounting hole drilling diagram included in the plans for the project.

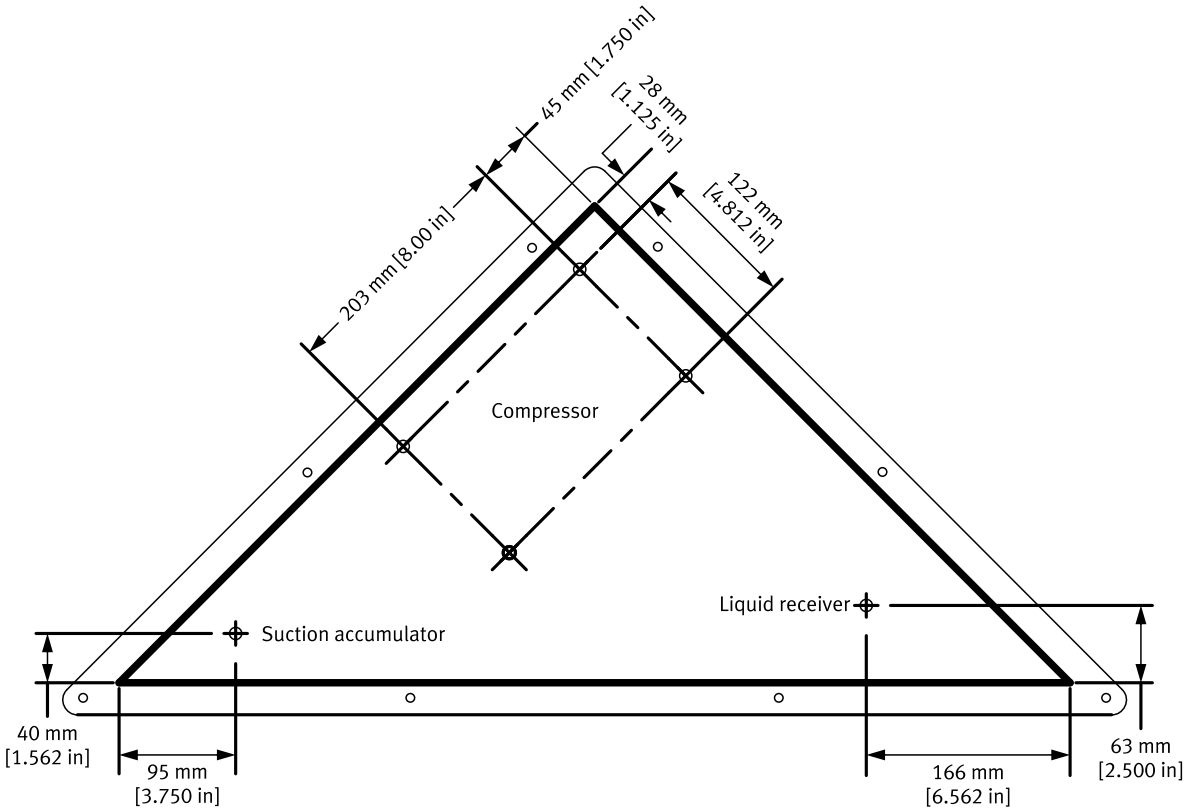

Figure 23. Diagram showing where to drill mounting holes for the compressor, suction accumulator, and liquid receiver.

3. Using a drilling tool, drill the mounting holes in the horizontal plate at the locations you marked previously.

It is suggested to use a small-sized drilling bit to drill the mounting holes at first, then enlarge the holes using a larger-sized one. This allows for easier centering of the holes.

Figure 24. Technician drilling the mounting holes in the horizontal plate.

4. Using the appropriate fastening tools, install the compressor, suction accumulator, and liquid receiver at their respective locations on the horizontal plate. The following figure shows the components mounted on the system.

Make sure to install rubber pads under the compressor mounting brackets to absorb shocks and vibrations. You will need to open the compressor to do this.

For more information on how to install the compressor, suction accumulator, and liquid receiver, consult the following video.

Technician installing the compressor, suction accumulator, and liquid receiver

https://ip.festo-didactic.com/FDCAQRCodes/qrcode0047.html

Installation of the condenser and fan

40 min.

Competency

- *Be able to assemble and mount a condenser and fan on a platform according to an installation diagram.*

In this section, you will install the condenser on its platform, on the upper-right portion of the system. You will also install the fan behind the condenser.

5. Locate and retrieve the following components and tools:
   - Condenser
   - Fan motor and blade
   - Screw and fastener kit for the condenser (bag 5)
   - Tools for fastening screws and nuts (e.g., screwdriver, wrench)

6. Using the appropriate fastening tools, install the condenser on its platform, in the upper-right portion of the system.

7. Screw the fan blade on the fan motor. Then, install the fan behind the condenser, in the appropriate slots. The following figure shows the condenser and the fan installed on the platform.

Figure 25. Condenser and fan installed on the platform.

Part 4 - Work Assessment

Evaluation criteria

To assess the work performed by the students in this exercise, it is recommended to use the evaluation criteria presented in the following subsections. These criteria cover the following main components:

1. *Evaporator coil and heat recovery coil*
2. *Heat recovery circuit*
3. *Compressor, suction accumulator, and liquid receiver*
4. *Condenser and fan*

Evaporator coil and heat recovery coil

It is recommended to use the following evaluation criteria to assess the work performed on the evaporator coil and heat recovery coil:

- *Both coils follow the specifications given in their respective piping diagrams.*
- *Both coils fit correctly in their respective basins.*
- *The bends in the coils are made according to industry standards, both in terms of bending angle and quality.*
- *The evaporator coil was made within 60 minutes.*
- *The heat recovery coil was made and finished within 120 minutes.*

Heat recovery circuit

It is recommended to use the following evaluation criteria to assess the work performed on the heat recovery circuit:

- *The circuit follows the specifications given in their respective piping diagrams.*
- *The two solenoid valves and two ball valves are installed according to the piping diagram specifications, with the correct orientation.*
- *The circuit is leak tight when pressure-tested at 10 bar for 10 minutes. Note: this criterion can be evaluated after Exercise 2, when the piping has been completed.*
- *The bends in the circuit are made according to industry standards, both in terms of bending angle and quality.*
- *All brazed joints in the circuit are made according to industry standards, both in terms of tightness and quality. Furthermore, copper-to-copper joints have been brazed using nitrogen.*
- *The heat recovery circuit was assembled and brazed within 120 minutes.*

Compressor, suction accumulator, and liquid receiver

It is recommended to use the following evaluation criteria to assess the work performed on the compressor, suction accumulator, and liquid receiver:

- *The compressor, suction accumulator, and liquid receiver are installed at the locations indicated in the mounting hole drilling diagram.*
- *The compressor, suction accumulator, and liquid receiver were installed within 75 minutes.*

Condenser and fan

It is recommended to use the following evaluation criteria to assess the work performed on the condenser and fan:

- *The condenser and fan are installed at their respective locations according to industry standards.*
- *The condenser and fan were installed within 40 minutes.*