Electricity and New Energy
EDS® Solar Thermal

Solar Thermal Energy Systems

Courseware

Sample 52668-F0

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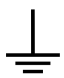
Safety and Common Symbols

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. Consult the relevant user documentation.
	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
	Earth (ground) terminal
	Protective conductor terminal

Safety and Common Symbols

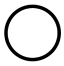
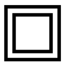
Symbol	Description
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

Table of Contents

Preface

The EDS® Solar Thermal, Model 46121, is a modular program that covers the history, fundamentals, installation, operation, maintenance, and servicing of solar thermal energy systems.

From now on, the EDS® Solar Thermal will be referred to simply as the solar thermal training system.

The curriculum is divided into the following topics:

- Introduction to solar thermal energy
- Solar thermal energy systems
- Multi-loop systems

⚠ WARNING

The solar thermal training system should be operated under supervision at all times. Never let the system operate unattended.

⚠ WARNING

Be careful to prevent water from making contact with electrical components. Use a bucket and mop if some leakage occurs.

⚠ CAUTION

The surface of the work lights can become very hot. Whenever you manipulate them, take great care to avoid direct contact with the skin.

⚠ CAUTION

Be careful when rotating the solar collector. Improper use can lead to injuries.

CAUTION

The maximum operating temperature of the liquid inside the system is 50°C. If this temperature is reached, stop the system operation, turn the lights off, or cover the solar collector.

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 topics covered in this manual are presented in the form of job sheets. The job sheets include a description of the objectives, a list of equipment required, a list of safety procedures, and a list of steps required to attain the objectives.

The topics are introduced in an Information Job Sheet. However, to obtain detailed information about the covered topic, you should refer to your textbook or ask your instructor to guide your learning process.

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.

Reference Textbooks

Refer to the textbook titled Solar Water Heating written by Bob Ramlow & Benjamin Nusz.

Appendices

The appendices included in the manual are:

Appendix A: *Equipment Utilization Chart*, shows in which Job Sheet(s) the equipment is used.

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

Appendix C: *System Filling and Draining Procedures*, contains system filling and draining procedures specific to the solar thermal training system.

Appendix D: *Schematic Diagram Symbols*, shows a variety of commonly used schematic symbols that represent electrical components that may appear in diagrams throughout this manual.

Appendix E: *System Troubleshooting*, lists common symptoms and causes of system failures.

Appendix F: *Electrical Wiring Instructions*, provides information on the electrical wiring of the training system.

Appendix G: *Work Assessment Table*, provides a table allowing the instructor to assess the students' work in the exercises (Instructor Guide only).

About This Manual

Improvements

Equipment is constantly improved by manufacturers to maintain state-of-the-art quality. Therefore, you may discover some discrepancies between the instructions and/or graphics in the course and the actual equipment. To ensure correct setup and operation, always consult the latest equipment user guide.

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, ensure 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 already partially mounted, ensure that the setup corresponds to the job description.
- This guide provides you with the answers to calculations, measurements, and review questions. Your evaluation, however, must relate to the quality of the accomplished work. Make sure that the objectives listed in the Work Assessment Table are met.
- When the jobs are performed in teams, ensure that each student has and installs a padlock when performing the lockout/tagout procedure.
- Make sure that the students understand the objectives of the job to do. They should have read the appropriate pages in their textbook.

Sample

Extracted from

Job Sheets - Instructor

Solar Heating and Cooling Systems

The solar thermal training system provides hardware and curriculum for experimenting with solar heating systems. Although solar cooling systems may be briefly mentioned throughout this learning material, the training system primarily focuses on solar heat.

Solar energy can be used to heat (or cool) liquids, gases, and solids, such as water, air, and surfaces. There is a wide variety of different methods that are commonly used to accomplish this task in an effective manner.

System types

Many different types of solar thermal energy systems are commonly used today. The following list describes some of these systems.

Passive and active systems

Passive solar thermal energy systems typically use building-integrated components for solar collecting and heat transfer or thermal storage. These systems mainly rely on principles of stratification or natural convection and are called thermosiphoning systems. They often require few or no moving parts to operate. Generally, this type of system uses only power from the sun to operate. Even if electric pumps or blowers are used, they are commonly powered by a photovoltaic (PV) solar array. These simple power systems may cost less and usually require less maintenance once functioning properly, but they require careful design and construction, and cannot always overcome challenging heating and cooling demands, while ensuring comfort to the homeowner.

Active solar thermal energy systems use externally powered fluid movers, such as utility-powered circulating liquid pumps or gas blowers to provide pressure and flow for the transfer and storage media. Electrical and/or electronic controls are most commonly used to activate and de-activate these circulators based upon various system temperatures that are automatically measured and monitored over time by the controller.

Open-loop and closed-loop systems

An open-loop solar thermal energy system is a heating or cooling system that uses heat storage. It is vented in at least one area. Often, the transfer medium and the storage medium are one fluid. For example, in a solar-heated swimming pool system, the transfer fluid (chemically-treated water) in the solar collector array is the same fluid that is stored in the pool.

A closed-loop solar thermal energy system is a heating or cooling system that uses a heat exchanger to transfer thermal energy from one fluid to another fluid through a barrier wall, which keeps the transfer medium isolated from the storage medium. For example, in a solar-powered domestic hot water (DHW) system the transfer fluid (water mixed with antifreeze) never mixes with the stored potable (drinkable) water. Closed-loop solar thermal energy systems often have potential to overheat.

Direct and indirect systems

Direct systems use collector-heated water directly to heat other areas of the system. Direct systems heat fluid within the solar collector, and use that fluid for both heat transfer and storage. Direct systems for domestic water supplies often require a water softener to prevent the solar collector and other system components from clogging, due to potential calcium build-up.

Indirect systems do not store collector-heated water directly, but instead heat the stored water indirectly by transferring heat into the storage medium. Indirect systems heat a transfer fluid within the solar collector, and use a heat exchanger to heat the storage fluid.

Other specialized systems

A flooded system is one that has fluid in the solar collector and pipes at all times. It also has a storage tank connected directly to the solar collector, which means that this is a direct, open-loop system. A recirculation system is similar to a flooded system, but it can recirculate warmed fluid throughout the entire system to prevent it from freezing. However, this process adversely affects overall system efficiency.

A draindown system drains its fluid when not in use, and a drainback system fills the solar collector and collector loop with fluid when solar energy is available for harvesting, but drains the fluid back into a storage tank when not collecting solar energy. Draindown systems are usually direct and drainback systems are usually indirect.

Combination systems provide solar heating to both water and space (air and/or surfaces). Integrated systems combine a solar heating (and/or cooling) system with a traditional (fossil fuel) heating (and/or cooling) system. Solar integration with conventional fossil fuel (natural gas/ propane/electric) systems is common in existing residential homes. The use of commercially available air handlers helps to simplify the installation and operation of such a system. A diversion system can use an outdoor shunt loop to offload or divert excess collected thermal energy away from an indoor thermal load, such as a concrete slab or another high-mass thermal storage device. This prevents system overheating and potential damage to the heat store. A dump system simply dumps its collected thermal energy to the point of use without any capability of thermal storage. Multimode systems simply utilize both thermal storage and heat exchange techniques. A storage-in-crawl-space solar heating/cooling system uses active air flow and integrates a high-mass thermal storage area into the bottom of a residential home.

Passive hydronic systems, as shown in Figure 1 and Figure 2, have the following advantages and disadvantages.

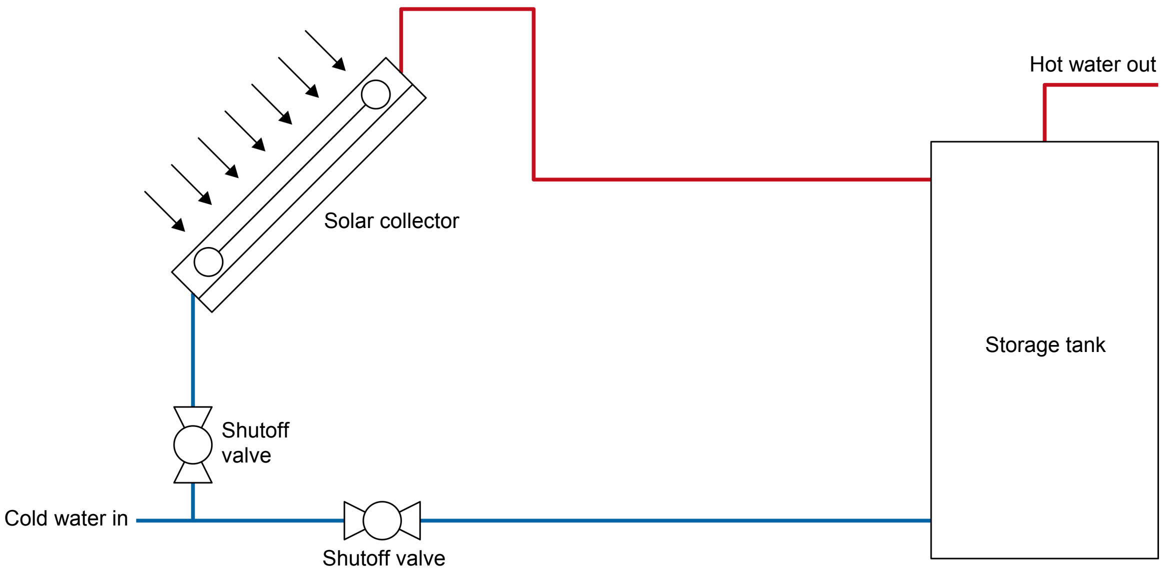


Figure 1. Passive, direct, open-loop, ICS (batch), water-heating system.

Passive, direct, open-loop, vented, integrated collector storage (ICS) or batch water heating with storage

Advantages

- Efficient operation
- Good for warm climates
- Low-maintenance
- Less plumbing required
- No electricity needed for fluid circulation
- Saves space without an external storage tank

Disadvantages

- Requires water softener for domestic hot water (DHW) applications
- Can freeze easily; not for cold climates
- Solar collector weight can make roof installations difficult

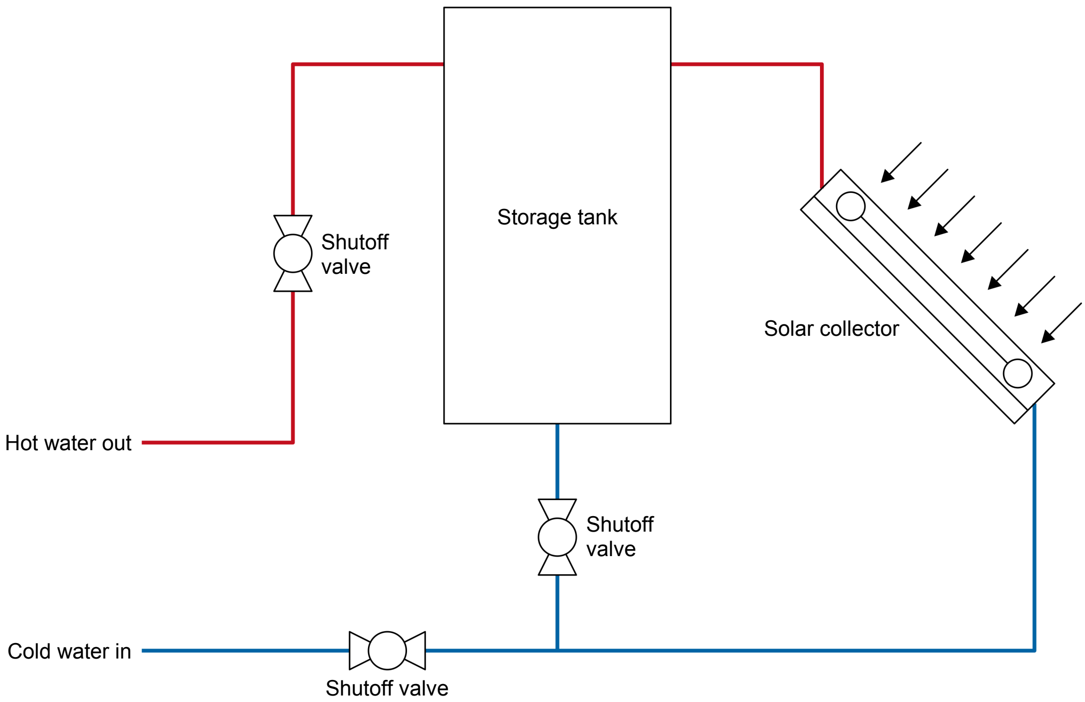


Figure 2. Passive, direct, open-loop, TWP, water-heating system.

Passive, direct, open-loop, vented, thermosiphoning water panel (TWP) water heating with storage

Advantages

- Efficient operation
- Good for warm climates
- No electricity needed for fluid circulation
- Low maintenance
- Space-saving

Disadvantages

- Storage tank must be placed above solar collector
- Storage tank weight can make roof installations difficult
- Requires water softener for domestic hot water (DHW) applications
- Can freeze easily; not for cold climates

Active hydronic systems have a vast range of benefits, as well. Figure 3 shows one common example of an active, direct, open-loop, draindown system for heating chlorinated (or brominated) water that is normally used in swimming pools, hot tubs, and spas.

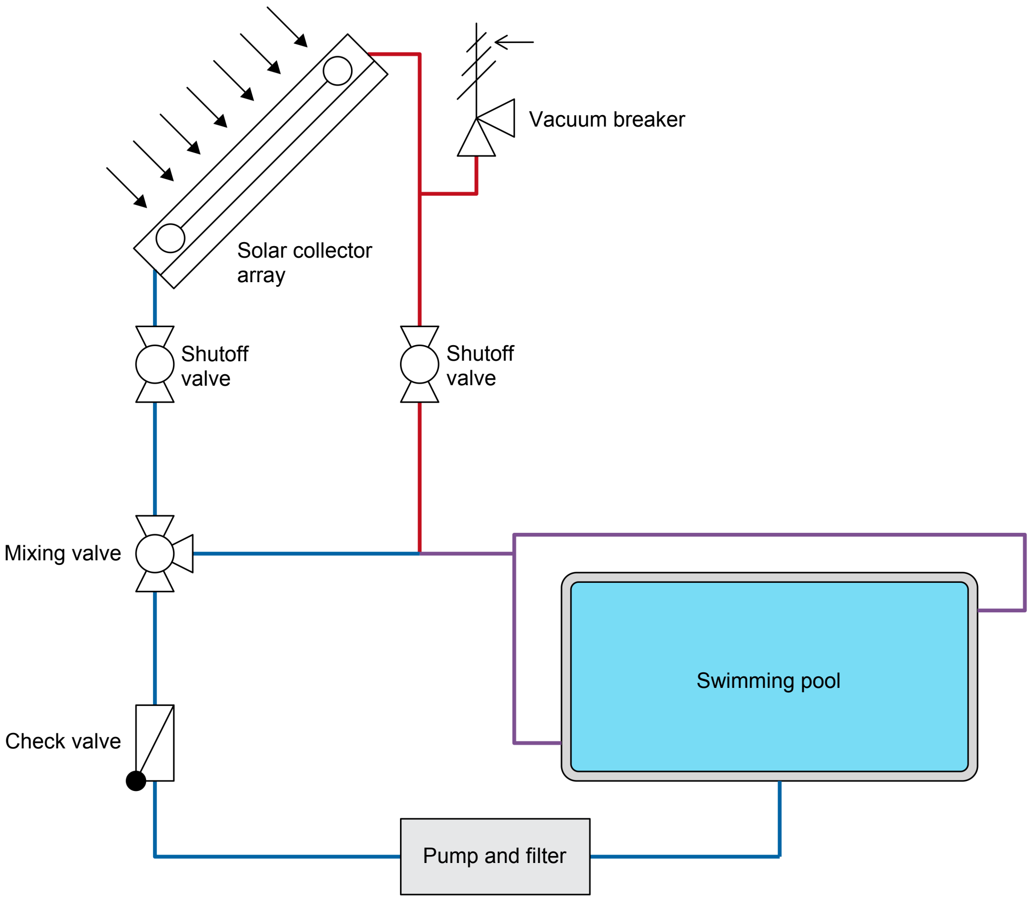


Figure 3. Active, direct, open-loop, draindown, water-heating system.

Both seasonal (outdoor) and year-round (indoor) swimming pools can be solar heated. Active hydronic systems such as this one have the following advantages and disadvantages.

Active, direct, open-loop, vented, draindown (water) heating with storage

Advantages

- Very efficient (even more than ICS)
- Storage tank connected directly to solar collector with circulator pump
- Uses low-profile, lightweight solar collectors

Disadvantages

- Can freeze easily; not for cold climates
- Uses special (auto draindown) valve that is prone to failure

Freezing and overheating protection

Draindown and drainback systems are often used to provide some freeze protection. Freeze valves offer only minimal freeze protection. Freezing is most effectively avoided by using antifreeze fluids, such as a glycol-water mixture as the transfer fluid. Automatic recirculation can also be used to warm a nearly frozen solar collector with storage tank hot water, but this technique reduces overall system efficiency.

Overheating of system components can be a problem in very sunny areas or when a pump fails. Pressure relief valves help to reduce excess water pressure and to release steam in closed-loop systems. Active systems can circulate the system water through the solar collector array at night to help cool down a hot storage tank. A diversion system can also be used to bypass an indoor thermal storage load and route excess heat outdoors.

Air and water quality

In any residential system installation, the quality of the air and water in the home is of the utmost importance. Special techniques are usually applied during system design and installation to ensure sufficient air flow throughout the home to help reduce moisture and humidity, minimize condensation, and prevent mold and mildew growth while allowing fresh outdoor air to enter the home in order to improve the indoor air quality (IAQ). Extra measures are often taken to maintain safe potable drinking water within the household as well. Air and water filters, and double-walled heat exchangers, help to ensure that consumer safety is not compromised.

Regulations

There are many legal regulating bodies that establish and maintain standards and codes for building, plumbing, HVAC/ducting, electrical wiring, mechanical safety, and fire protection. Federal, state, and local governing bodies require that certain safety standards be met when installing heating and cooling systems.

In the United States, some industry standards in solar thermal energy technology come from the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) (www.ashrae.org), such as Standard 90.1, the U.S. Department of Energy (DOE) (www.energy.gov), the U.S. Environmental Protection Agency (EPA) (www.epa.gov), the National Institute of Standards and Technology (NIST) (www.nist.gov), and the Council of American Building Officials (CABO). U.S. organizations write codes that impact electrical wiring safety, such as the ANSI/NFPA 70 National Electrical Code® (NEC®) (www.necplus.org), which was written and is maintained by the National Fire Protection Association (NFPA) (www.nfpa.org), and was approved by the American National Standards Institute (ANSI) (www.ansi.org), a broader-based standards committee.

Plumbing and mechanical codes also exist for the U.S. and international communities, such as the Uniform Plumbing Code (UPC), the Uniform Mechanical Code (UMC), the Uniform Swimming Pool, Spa, and Hot Tub Code (USPSHTC), and the Uniform Solar Energy Code (USEC), developed by the International Association of Plumbing and Mechanical Officials (IAPMO) (www.iapmo.org). Codes and standards for the HVAC&R industry include the Model Energy Code (MEC), published by the International Code Council (ICC) (www.iccsafe.org), the National Air Duct Cleaners Association (NADCA) (www.nadca.com), and the Air Conditioning, Heating, and Refrigeration Institute (AHRI) (www.ahrinet.org).

Building codes often involve fire prevention as a major component, such as the International Building Code (IBC) written by the International Code Council (ICC). Efficiency is also a primary focus in building energy codes, as with the certified ratings by the National Fenestration Rating Council (NFRC) (www.nfrc.org).

International codes and standards include the International Energy Conservation Code (IECC), developed by the International Code Council (ICC), and the International Energy Agency – Solar Heating and Cooling Program (IEA-SHC). Many states have their own local codes as well.

Careers

Installing and maintaining solar thermal energy systems is one aspect of careers available within the heating, ventilation, and air-conditioning (HVAC) industry. Required HVAC trade skills include knowledge and experience in construction, wiring, plumbing, and/or ducting. System design and the selection of solar components are also important aspects of the industry for architects and engineers. Construction contractors and managers are required to ensure that the labor force, materials handling, and work flow are organized and scheduled to complete each project effectively.

Specialized jobs, such as an energy auditor or other weatherization positions, are also available in the challenging and rewarding field of solar thermal energy technology. Solar thermal energy offers a wide choice of positions at many different education and skill levels, which can be considered when choosing a career path for yourself.

Manufacturers

Solar thermal energy components are manufactured by companies that combine raw materials and small purchased parts with fabrication and assembly processes to produce major system parts and equipment, such as racks and other mounting systems, solar collectors, differential controllers, heat exchangers, storage tanks, circulator pumps and blowers, valves, and fittings. Many manufacturers design and develop the products that they produce.

Integrators

Manufacturers and even some distributors and retailers prefer to sell solar thermal energy components directly to system integrators that offer many different services to consumers, such as analyzing, designing, building, installing, monitoring, and maintaining complete solar thermal energy systems.

Providers

Utility-scale power-producing companies distribute and provide electrical power from giant concentrating solar collector arrays to large areas, such as local communities and cities. The structure and operation of such a massive organization requires a vast variety of workers and skill sets.

Many people that are employed in the solar thermal energy arena can become members of professional organizations, associations, or societies, such as the American Institute of Architects (AIA) (www.aia.org) and the Institute of Electrical and Electronics Engineers (IEEE) (www.ieee.org).

Certifications

Professional certifications can be obtained in the solar thermal energy industry as well. Many of the standards and codes organizations (mentioned previously) perform certification testing to ensure that trained workers are properly applying the published codes. For example, building inspectors must be trained and certified to validate that they know what to look for during an on-site inspection. Some commonly available certifications for solar thermal energy include the Leadership in Energy and Environmental Design® (LEED®) program for green design, construction, and operation, administered by the U.S. Green Building Council (USGBC®) (www.usgbc.org), the North American Board of Certified Energy Practitioners (NABCEP) (www.nabcep.org) certification for system installers, and the many certifications available from the International Code Council (ICC) (www.iccsafe.org/Accreditation).

System performance

This job involves installing and operating a single open-loop water (flooded or recirculation) heating system, which has the following advantages and disadvantages.

System type

Active, direct, open-loop, vented, flooded or recirculation (water) heating with storage

Advantages

- Very efficient (even more than ICS)
- Storage tank connected directly to solar collector with pump
- Recirculation helps with freezing, but not good for extended periods
- Can use low-profile, lightweight solar collectors

Disadvantages

- Requires water softener for domestic hot water (DHW) applications
- Can freeze easily; not for cold climates
- Water in collector/pipes at all times
- Recirculation helps with freezing, but not good for extended periods

Solar Heating and Cooling Systems

OBJECTIVE

In this job, you will install a single open-loop water (DHW) heating system, called a flooded or recirculation system, as part of a solar thermal energy system. This open-loop configuration is a direct and active system that is mildly similar to a solar heating system for swimming pools.

PROCEDURE

Equipment required

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required for this job.

Safety procedures

Before proceeding with this job, complete the following checklist.

- ❑ You are wearing safety glasses.
- ❑ You are wearing safety shoes.
- ❑ You are not wearing anything that might get caught such as a tie, jewelry, or loose clothes.
- ❑ If your hair is long, tie it out of the way.
- ❑ The working area is clean and free of oil.
- ❑ The floor is not wet.
- ❑ Your sleeves are rolled up.
- ❑ The wheels of the system are locked in place.

Installation

1. Figure 4 shows a direct solar heating system with thermal storage.

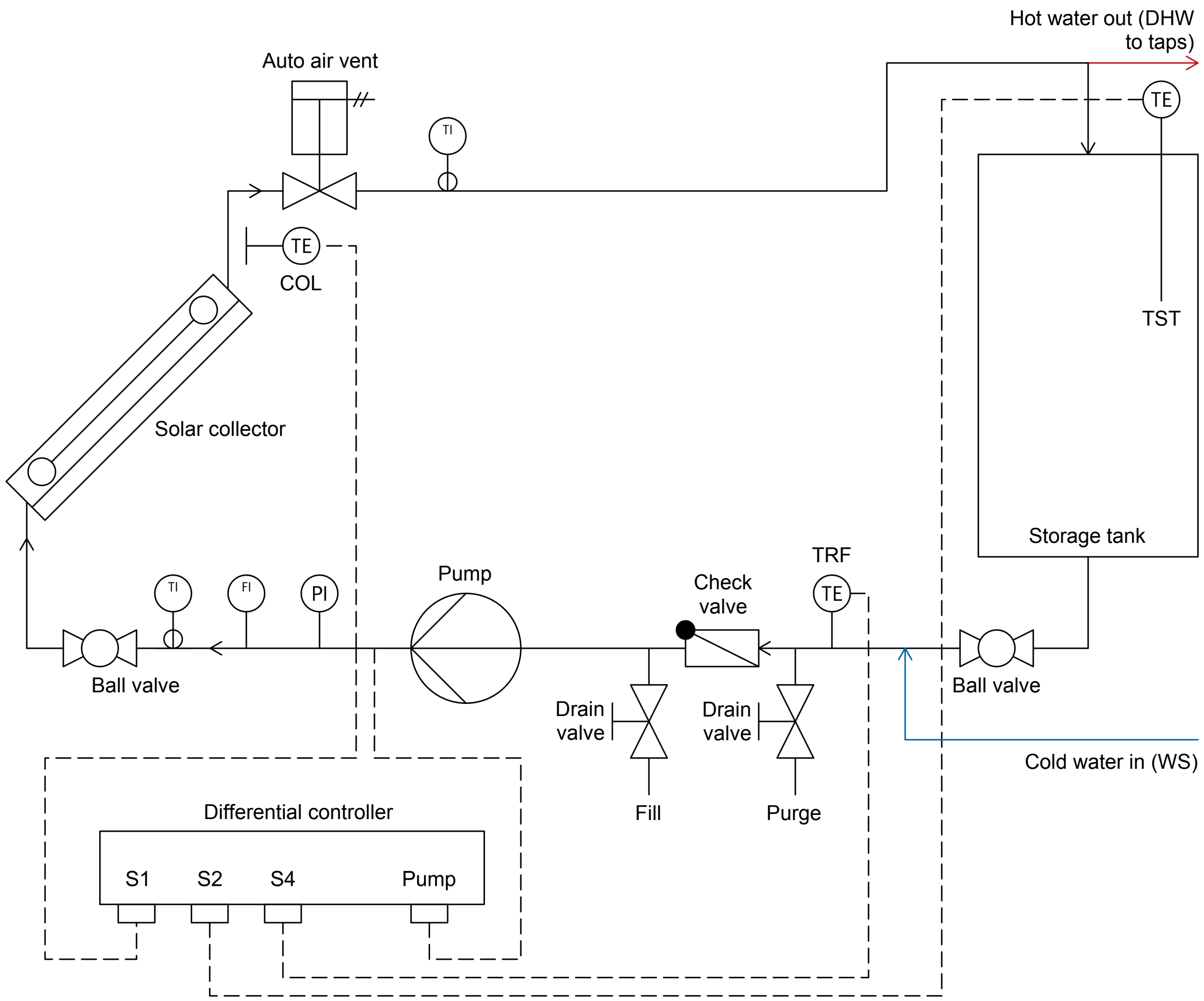


Figure 4. Open-loop, flooded/recirculation system schematic.

2. Ensure that the following parts are mounted on the mobile workstation as shown in Figure 5.
   - Solar collector
   - Circulator pump
   - Storage tank
   - Differential controller (with 3 sensors)
   - Thermometers (2)
   - Rotameter
   - Pressure gauge
   - Check valve assembly
   - Automatic air vent
   - Electrical panel

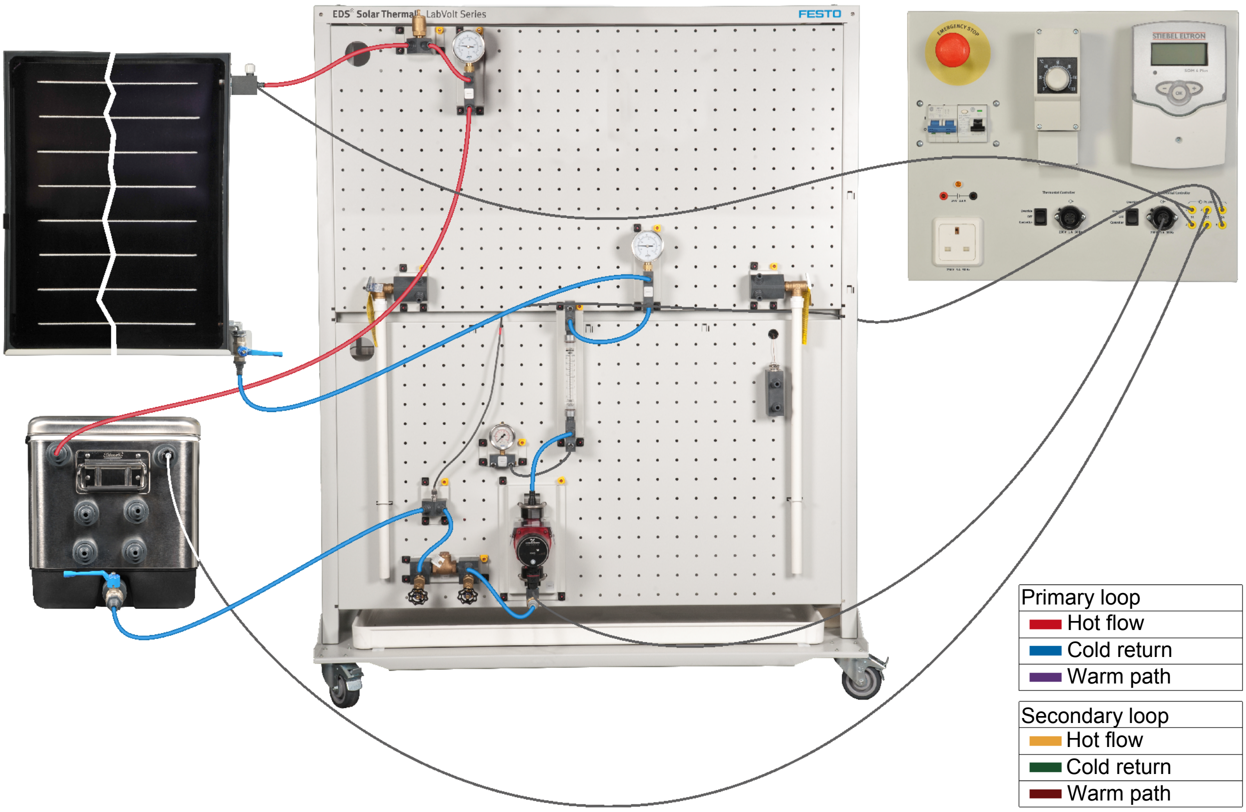


Figure 5. Open-loop, flooded/recirculation system configuration.

3. Ensure that the electrical wiring is complete by referring to the electrical wiring instructions in Appendix F.

4. Adjust the solar collector tilt angle to 90° (vertical) to simplify illumination.

CAUTION

Be careful when rotating the solar collector. Improper use can lead to injuries.

5. Connect the necessary hoses as shown in Figure 4 and Figure 5.

Always use the minimum hose length required for each circuit connection.

6. Connect the training system to an ac power source.

7. Fill the system with water (you can refer to the System filling procedure in Appendix C).

WARNING

Be careful to prevent water from making contact with electrical components. Use a bucket and mop if some leakage occurs.

8. Turn the power on by setting the circuit breaker to I.

9. Start the pump by setting the differential controller override switch to Override.

Then, set the pump to III.

Trapped air evacuation

The procedure to evacuate the air present in the system is called priming procedure (refer to Appendix C). To complete this procedure, follow these steps:

10. Set the valves of the solar collector to Open and stop the pump by setting the override switch to the Off position.

11. Disconnect the hose at the output of the pump and wait until you see a small flow of water.

12. Reconnect the hose at the output of the pump and start the pump by setting the differential controller override switch to Override.

Look at the rotameter indicator.

- If the value indicated is 0, close to 0, or oscillating, air is still present in the system. In this case, turn the pump off using the override switch, wait at least 5 seconds for the air to be evacuated from the pump impeller, then proceed to the next step.
- If the value indicated is equal or superior to 1.9 L/min, proceed directly to the Commissioning section of this procedure.

A flow of 1.9 L/min or higher is enough to perform all of the job sheets in this manual. Therefore, if the pump operates at a power higher than 30 W, it is a good indicator that the system is primed.

13. Restart the pump using the differential controller override switch. If the value indicated by the rotameter is still 0, close to 0, or oscillating, perform the following steps:

1. Disconnect the hose at the input of the rotameter. Let all trapped air be evacuated. You will know that air is no longer present when the water flow out of the hose becomes constant.
2. Disconnect the hose at the input of the thermometer. Let all trapped air be evacuated. You will know that air is no longer present when the water flow out of the hose becomes constant.
3. Restart the pump.
4. Repeat the process as often as necessary until water flow is constant.

You may have to restart the pump between five and fifteen times.

14. To optimize the system's priming, disconnect the other connections to evacuate all trapped air. However, it is usually not necessary since the system will stabilize by itself.

Commissioning

15. Set the valves as shown in Table 1.

Table 1. State of the different valves.

Valves	State
Automatic air vent	closed
Solar collector ball valve	open
Storage tank ball valve	open
Check valve assembly (fill) drain valve	closed
Check valve assembly (purge) drain valve	closed

16. Set the differential controller override switch to the Controller position.

17. Use the differential controller (TDIC) to set the pump to AUTO mode. To do so, press and hold the + (right) button on the controller until a new menu appears. Then, use the + button to select the MAN-1 menu. Press the OK (center) button and use the + and - buttons to select the AUTO mode. Press the OK (center) button to confirm.

18. Measure (with the pump on) the different parameters listed in Table 2, then record the values in the "Initial " column of the table. After that, position and power up the two 500 W work lights so that most of the radiant energy floods the solar collector panel evenly.

The pressure gauge port must be vertically level with the rotameter pressure port.

If the rotameter does not indicate any flow, it means that the controller has turned the pump off.

WARNING

The solar thermal training system should be operated under supervision at all times. Never let the system operate unattended.

CAUTION

The surface of the work lights can become very hot. Whenever you manipulate them, take great care to avoid direct contact with the skin.

Table 2. Test results.

Device	Values for different measuring times			Units
	Initial	At 15 min	At 30 min	
F1-1 (flow rate)				L/min
PI-1 (pressure)				kPa
TI (collector input)				°C
TI (collector output)				°C
TE-S1 (COIL)				°C
TE-S2 (TST)				°C
TE-S4 (TRF)				°C

Answers vary.

19. After about 15 minutes, measure (with the pump on) the different parameters listed in Table 2, then record the values in the "At 15 min" column of the table.

20. After about 30 minutes, measure (with the pump on) the different parameters listed in Table 2, then record the values in the "At 30 min" column of the table.

21. Use the differential controller override switch to turn the pump off.

22. Turn off the system by setting the circuit breaker to O.

Also turn off the work lights.

23. Disconnect the power cords and drain the system by performing the System draining procedure in Appendix C.

24. Using the data in Table 3, calculate the total volume of water contained within the system loop. Do not include the water in the storage tank.

The volumes indicated in Table 3 include the water in connection ports.

Table 3. System component volume.

Item	Description	Volume (L)
87042-10	1.82 m long hose with 1.27 cm inner diameter	0.23
87042-11	91.44 cm long hose with 1.27 cm inner diameter	0.12
87042-12	60.96 cm long hose with 1.27 cm inner diameter	0.08
87042-13	30.48 cm long hose with 1.27 cm inner diameter	0.04
89515	Solar collector	0.6
46508-1C	Circulator pump	0.20
87318-10	Storage tank 51.1 L (37.85 L max.)	37.85
87318-10	Coil heat exchanger (x2)	0.30
46505	Plate heat exchanger 0.11 L	0.11
46509	Temperature sensor (RTD)	0.03
52181	Thermostat controller (sensor)	0.05
46510-10	Expansion tank 7.95 L (4.16 L max.)	0.05
6531-C0	Radiator	0.26
46512	Radiant floor	0.16
46501	Thermometer	0.04
6550-A0	Rotameter	0.09
6553-E0	Pressure gauge (60.96 cm long hose with 0.46 cm inner diameter)	0.01
46503, 46504	Pressure relief valve	0.06
6520-A0	Shutoff valve	0.04
46507	Check valve assembly	0.12
46519-10	Fill bowl	0.05
46511	Automatic air vent	0.05

The thermostat controller (52181) is part of the workstation (46500-2C).

Each system component volume (in liters) includes the connection ports.

25. How much water is in the system loop?

2.16 L using hoses of the following lengths:

- two of 183 cm
- two of 91 cm
- two of 61 cm
- four of 30 cm

26. Ask the instructor to check your work.

Review Questions

1. Did the system work correctly?

   ❑ Yes ❑ No

   Yes

2. Describe and briefly explain the system behavior.

   The storage tank contents became warmer over time. This is because the solar collector stored energy in the storage tank.

3. Name a location or device in the system where thermal energy was transferred through a containment wall.

   Solar collector

4. Besides heating a swimming pool, where might a similar system prove to be effective or useful?

   A similar system could be used for solar heating a spa, hot tub, fish pond, or water garden, especially during the winter months in mild climates.

5. Based upon the measured values, what was the overall temperature rise of the water?

   About 1.7°C

Name: ______________________ Date: ______________

Instructor's approval: ______________________