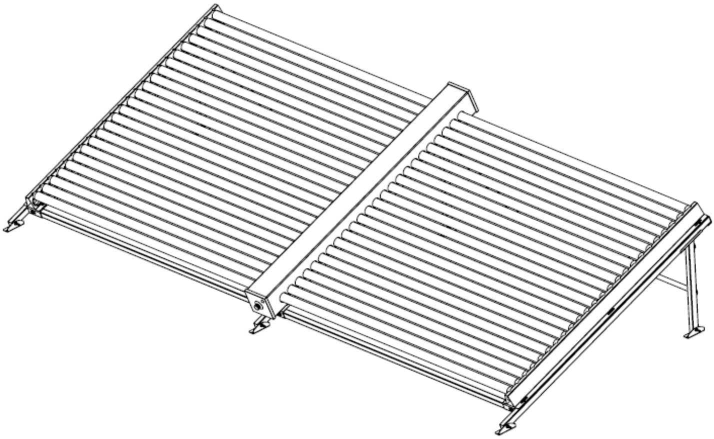

MILETUS
UNPRESSURIZED EVACUATED TUBE COLLECTOR

INSTALLATION, OPERATION & MAINTENANCE MANUAL

SİSTEM Tubular

www.sistemtubular.com

Revised on 27 April 2020

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TABLES

FIGURES

1. PRODUCT TYPE AND WARRANTY

Sistem Tubular produces unpressurized evacuated tube collector called as Miletus collector. There are 48 vacuum glass tubes mounted to a manifold in the system. The guaranty period of the collector is 2 years. The guarantee certificate is delivered with the product. The life expectancy of the collector is more than 20 years. On the other hand, system maintenance must be done regularly and system components that complete the service life have to be changed on time.

The estimated mean family consumption is around 40 litres daily per person at 45^{o}C water temperature. In this collector, it is recommended to use 250 liters water tank although it varies from region to region and it depends on type of usage. For example, Miletus has the capacity comfortably to meet the daily hot water consumption of up to 8 people.

2. GENERAL INFORMATION

This user manual contains all the necessary instructions about the introduction, installation, operation and maintenance of the product.

Sistem Tubular is a company that manufactures solar water heating systems. Using the high-tech equipment, developing new products with R & D activities towards needs, and increasing the productivity are among the priorities of the company. This product was developed considering the demands of the market as Miletus collector. It can be used either for domestic hot water consumption or for general purposes in hotels and large buildings as well as for other heating and cooling systems.

Nowadays, using alternative energy sources without polluting the environment to produce energy and increasing productivity have become a social responsibility. Renewable energy sources promise a solution to pollution as well as to the energy problem. The use of alternative energy products aimed to satisfy energy requirements without endangering the environment is increasingly encouraged by international legislation.

3. OPERATION OF THE COLLECTOR

3.1 INTRODUCTION AND WORKING PRINCIPLE OF VACUUM TUBE COLLECTOR

This product is an unpressurized evacuated tube collector. A pump must be used for the circulation of the water. At the same time, an external water reservoir should be installed to the system to increase the water storage capacity. Water tank might be placed under the roof or elsewhere in the building. Depending on the size of the circulation system, a proper pump size should be selected by the service provider. They are also responsible to choose the appropriate control unit of the pump and other parts which are not included in the system. The manufacturer is not responsible for supplying these necessary parts because they must be selected depending on the application and size of the system. Miletus collector provides comfortable and continuous usage of water with large water capacity.

It can be used either as an open-loop unpressurized system or a closed-loop system. That means you can use directly the heated water for your usage or in closed-loop system, heated water or liquid can be used to heat the usage water using an equipment in the reservoir tank such as double-wall, serpentine and, heat-exchanger. This model can also be integrated to building heating and cooling systems. Finally, placing a water reservoir on the top of the collector, it can be used without any pump as open-looped system to provide hot water.

The cold tab water, entering the water tank is pumped to the collector, is heated by solar radiation thanks to vacuum tube and becomes ready to use as hot water. This collector works in atmospheric pressure. Therefore, maximum water temperature in the tank reaches up to 99^{o}C especially in summer if water consumption is a little.

In this collector, there is no obligation to set it up in order to create a level difference as in other unpressurized systems because of having the pump. It can also be installed in the garden instead of the roof of the house to prevent visual pollution. It is also ideal for the top floors of the apartments.

3.2 WHAT IS ALL GLASS EVACUATED TUBE? HOW IT WORKS?

All glass evacuated tube consists of a two layers of glass with a vacuum in between the layers. The special selective coating on the outer surface of the inner tube changes solar radiation into the heat and then it is transferred to water. As long as the system is heated by the sun, the water continues to be heated.

4. SAFETY NOTICE

- If there is any leakage in the collector or system, in case of electrical connection, the mains electricity must be cut off. Then contact to the authorized service immediately.

- This manual is a part of the collector and please keep it. In case of lost, contact with the authorized dealer to get the new one. It can also be downloaded from the company's internet page.
- The collector you have received must be complete and in good condition.
- In case of any damage in the collector, contact with the authorized dealer.
- Assembly of the collector should be done by trained personnel.
- Installation of the collector should not be started until general work safety precautions have been taken.
- The collector must not be started until all safety equipment and control unit is installed and checked.
- The collector or it’s parts must not be modified or replaced without the approval of the manufacturer, Sistem Tubular.
- Care should be taken to ensure that children do not reach the hot water in the tank.

5. LABELING AND TRACEABILITY

Sistem Tubular’s Miletus collector has a life expectancy of more than 20 years. The collectors are identified by one product label on the collector. On this label, all the details of the collector are written. The information provided on the label is important for the future identification of the product. If the label is removed from the product, it will be difficult to identify the product and to fulfill the service and warranty procedure. The sample label is given in Figure-1.

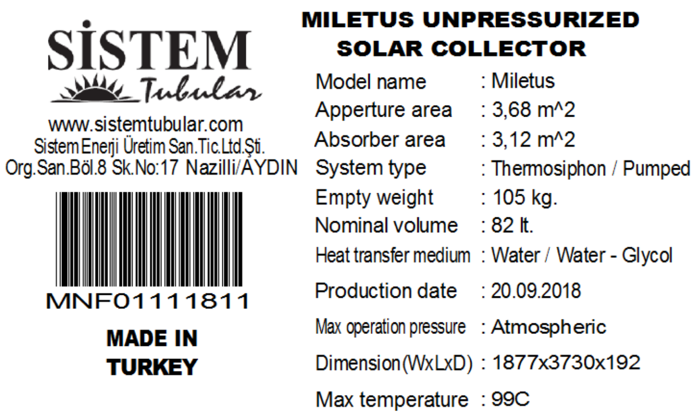


Figure-1. *Sample product label.*

6. TRANSPORTATION AND HANDLING INSTRUCTIONS

Vacuum tubes, solar water heater collector and, its components are packed in a cardboard box in which they are delivered to customers without any damage. During its transportation and handling, all safety indications on the packaging should be respected. Using Table-1 and Figure-3, please check whether the product is delivered to you without any missing parts. The packing materials must be removed from the collectors at the point of installation. Do not stand up on the product, it may cause serious damage and/or injuries.

7. GENERAL VIEW OF THE COLLECTOR, COMPONENTS AND SIZE

7.1. GENERAL VIEW OF THE COLLECTOR

This collector in Figure-2 is designed to operate with a water pump to supply the hot water needs of residential buildings or other applications. The collector does not have all the necessary equipment for this function because they must be selected depending on the application and size of the system. Some optional equipment also depends on the user's preference.

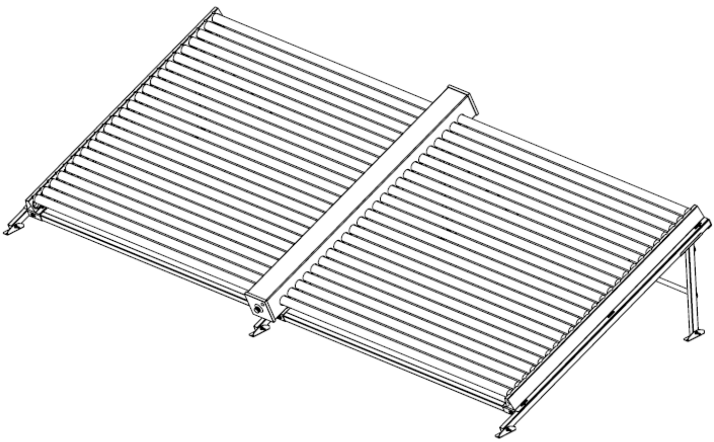


Figure-2. *General view of the solar water heater*.

7.2. COMPONENTS OF THE COLLECTOR

The assembly frame of the solar water heater is shown in Figure-3. The hot water tank might be placed under the roof or elsewhere in the building.

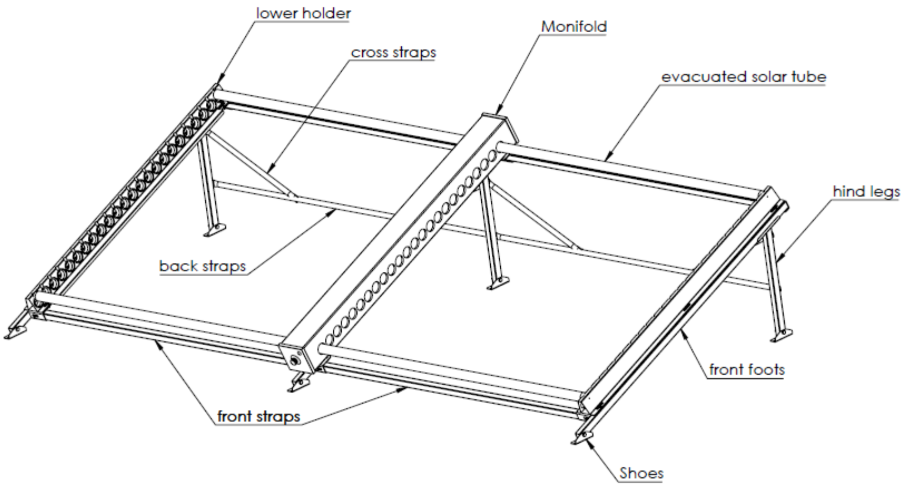
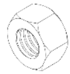


Figure-3. *Assembly of whole frame*

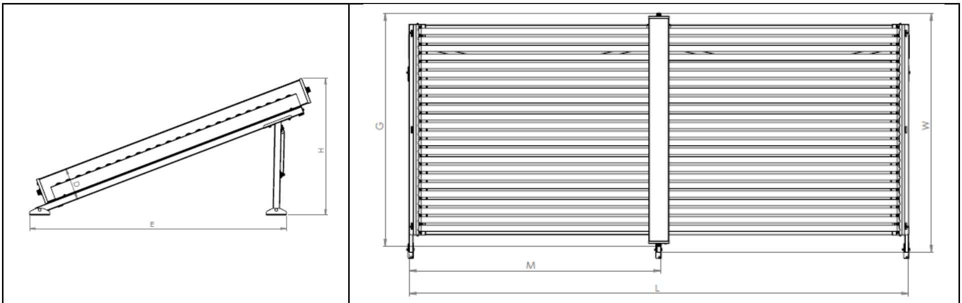
The other components in the collector are given in Table-1.

Table-1. *The components of the solar water heater.*

Model type/Name of component	Miletus Collector	view
Plastic support (piece)	48 + 2	
Dust seal (piece)	48 + 2	
Nuts	6	
Mounting bolts - M8 (L=20mm)	39	
Mounting bolts – 3/8” (L=80mm)	6	

7.3 SIZE OF THE COLLECTOR

Mounting dimensions of the collector to flat roof and tile roof are given in Figure-4. Table 2 also shows the dimensions of Miletus collector.



(a) flat roof	*(b) tile roof*

Figure-4. *Mounting dimensions of the collector*

Table-2. *Dimensions of the solar water heater.*

Collector/Dimensions	Miletus
E (m)	1.535
H (m)	815
M (m)	1.885
L (m)	3.740
G (m)	1.742
W (m)	1.787
D (m)	0.195

8. INSTALLATION OF THE COLLECTOR

8.1 NOTICES FOR INSTALLATION

Miletus water heating collector is usually installed on the roof but can also be installed on the ground because a proper pump is used for circulation of the water. Therefore, level of the installed place in terms of the usage comfort is not important.

The collector must be installed by authorized persons. The installer must comply with all safety regulations. In addition, all work associated with the installation must comply with local authority regulations, where these installation instructions and local regulations are in conflict, local regulations must prevail. All components of the collector are packaged and presented to the customer. Before installing the collector, check all components whether they are in good condition and the installation location (orientation and angle) of the collector whether it is proper. If the mounting area is snowy and/or windy, these situations should be taken into consideration. The collector must be installed by paying attention to the distances in Figure-5 so that it is not to be shadowed by an object or each other. The collector inclination angle in general is 44^o. However, it can be produced at different angles depending on the quantity of the order. It is possible to install multiple collectors to a smaller area using smaller inclination angle. This requires less shading space. Since the vacuum tubes are installed in horizontal direction, the angle *F* almost has no effect on the collector efficiency depending on the seasons or the latitude of the installation location. Unlike vertical systems, the main effect depends on the position of Sun during the day. The distances B and C between the collector and the obstacle or other collector are also given in Table-3 according to the latitudes. For example, Turkey is between latitudes 36 to 42 so *B = 2A and C = 2H* should be taken. Please contact the authorized dealer for further information.

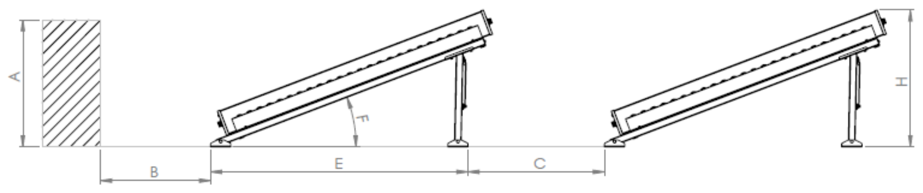


Figure-5. *Mounting distances to avoid shading*

Table-3. *B and C distances shown in Figure-5.*

Latitude	B	C
0^{o} - 25^{o}	1.0xA	1.0xH
26^{o} - 35^{o}	1.5xA	1.5xH
36^{o} - 45^{o}	2.0xA	2.0xH
46^{o} - 50^{o}	2.5xA	2.5xH
> 50^{o}	3.0xA	3.0xH

8.2 INSTALLATION

The supporting base or platform must be prepared before the installation of the collector(s).

First, assemble the front frame on which the vacuum tubes are mounted. Place the front legs, three pieces, on the floor (Figure-6). Nuts are fixed on the link bars to tighten them each other with bolts.

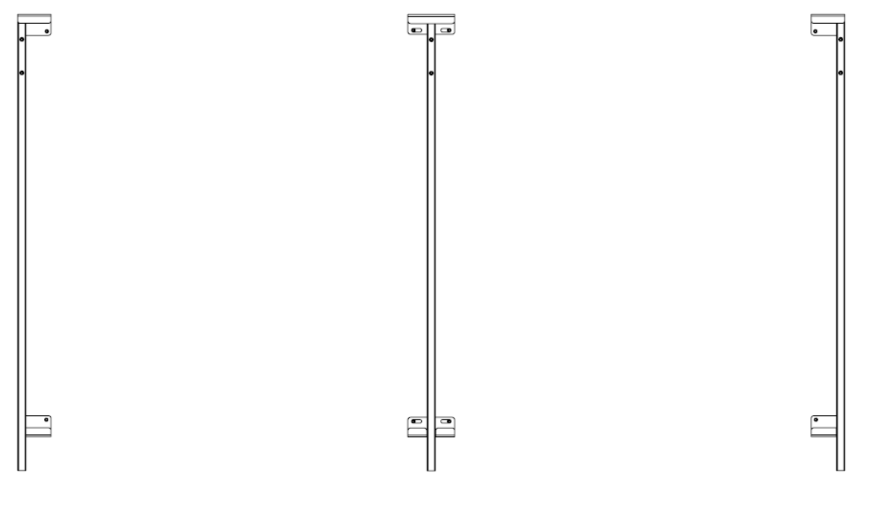
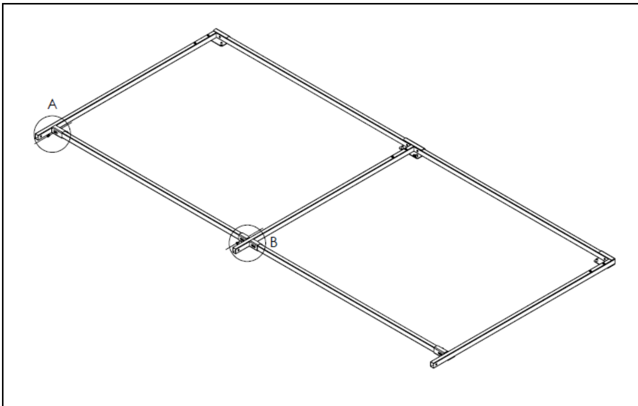
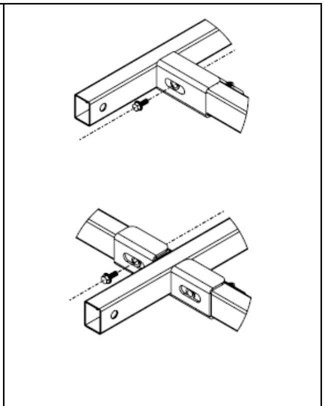


Figure-6. *Front legs*

Mount the link bars to the front legs and tighten the bolts (Figure-7). The completed front frame is shown in Figure-8.



(a) general view



(b) view A and B

Figure-7. *Mounting the link bars to the front legs*

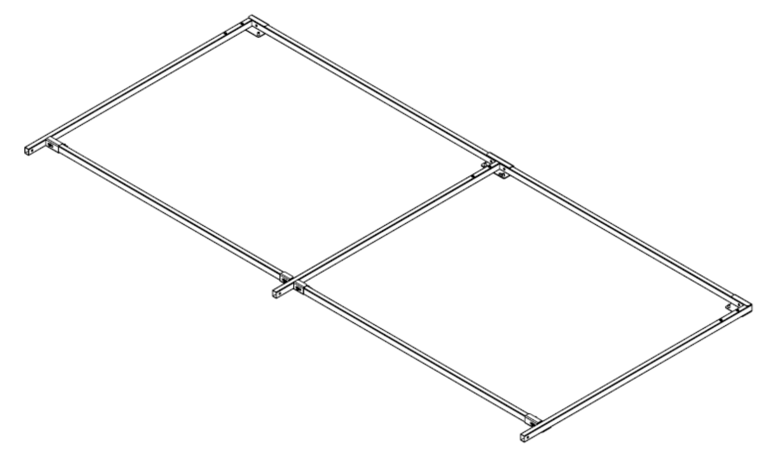
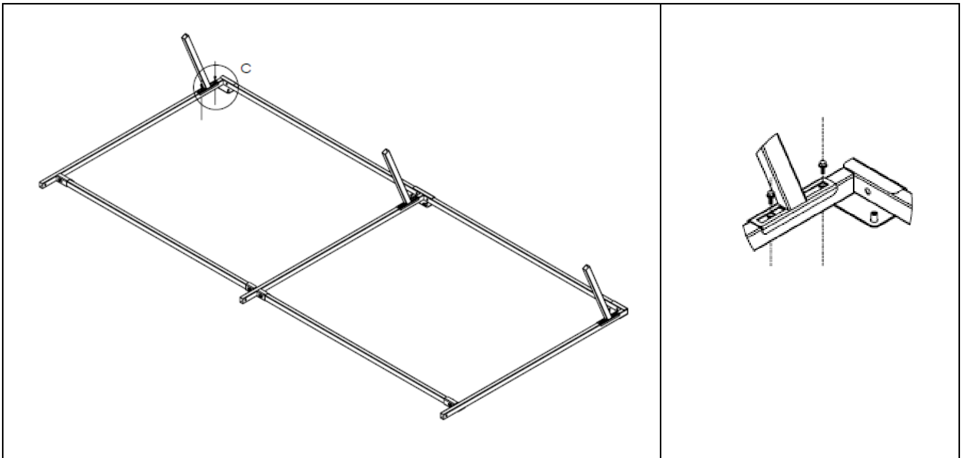


Figure-8. *Assembled front frame*

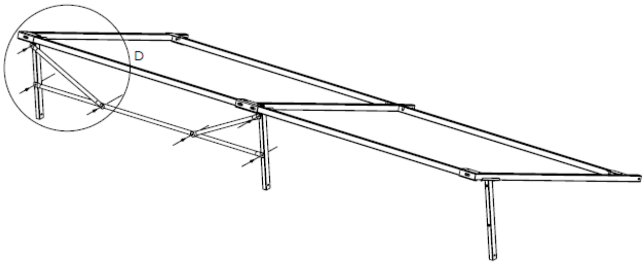
To place the rear legs of the frame, slide the channel until it touches the nut near the edge. In this way, align the rear legs and fix them with bolts (Figure-9).



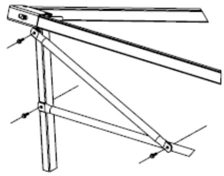
(a) general view	*(b) view C*

Figure-9. *Mounting the rear legs to the front frame*

Install the back straps and crosses of the rear legs using the bolts as shown in Figure-10 and Figure-11. The completed assembly of the frame can be seen in Figure-11.



(a) general view



(b) view D

Figure-10. *Mounting the back straps and crosses of the rear legs*

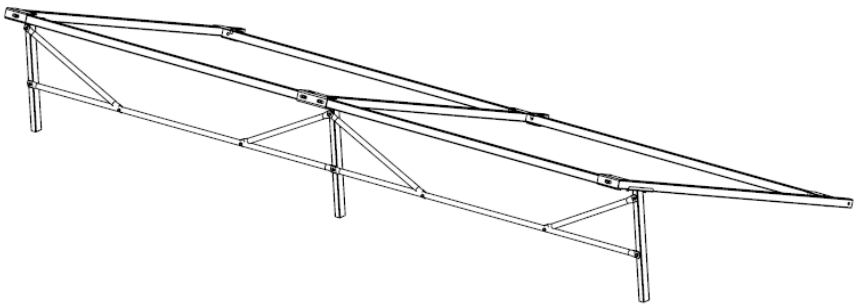
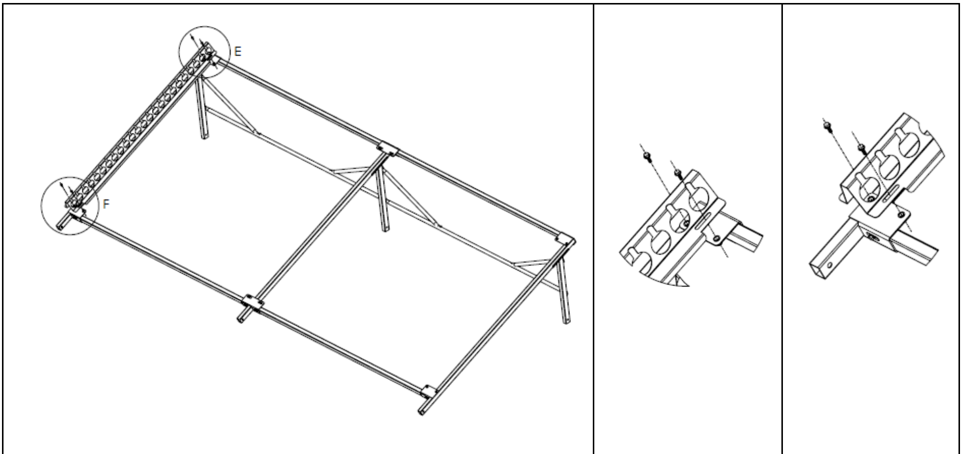


Figure-11. Assembly of the main frame

Place the left and right vacuum tubes’ lower holders to the front frame as seen in Figure-12 & 13. Do not tighten the bolts thoroughly because it may be necessary to move the lower holders up and down to adjust the angle of the vacuum tubes using an angle gauge.



(a) general view	*(b)* view E	*(c)* view F

Figure-12. *Assembling of the left vacuum tubes' lower holder to the front frame*

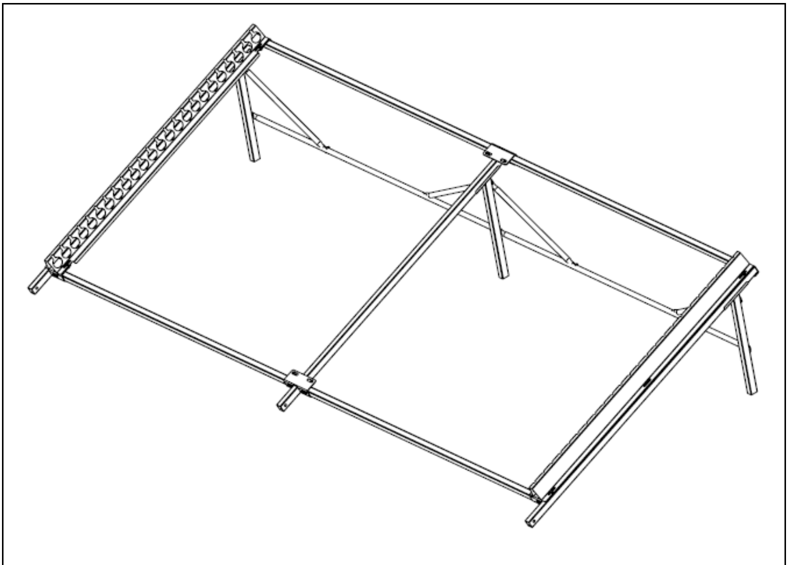


Figure-13. *Assembly of the both vacuum tubes' lower holders*

Mount the manifold to the middle part of the frame using the bolts (Figure-14). The nuts are fixed on the manifold. Do not tighten the manifold thoroughly because it will be checked whether it is on balance in the next step. The whole frame of the collector has been completed with this process.

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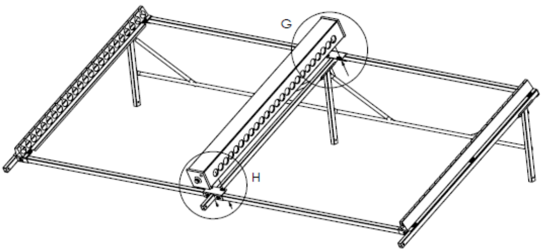
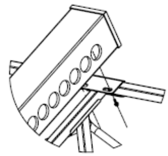
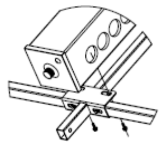
<tr><td>
</td><td></td><td></td></tr>
<tr><td>(a) general view</td><td>(b) view G</td><td>(c) view H</td></tr>
<tr><td colspan="3">Figure-14. Mounting of the manifold</td></tr>
</table>

To check the collector whether on balance, prepare 4 vacuum tubes and place them as one on the top and one on the bottom locations for each side (Figure-15). Before doing this, first place the plastic supports in only one side of the bottom holder; let's say to the left side. Otherwise, width of the collector is not enough to mount the other side. Mount the dust seals to the vacuum tubes and install the tubes to the left side. To install the vacuum tubes to the right side, hold a tube and plastic support together. Align it to its place in the lower holder and locate it. Installation of the vacuum tubes is explained below under the title of "**CONSIDERATIONS DURING THE INSTALLATION OF VACUUM TUBES"** in this section. Check the vacuum tubes whether they enter an equal amount in the manifold. If the vacuum tubes on one side enter in the manifold much more than the other side, sliding the manifold on the slot, adjust the entered distances in an equal amount. If there is no any tension and the vacuum tubes are properly placed, tighten 4 bolts firmly in the manifold.

Heated water goes upward with the natural circulation. Therefore, the frame is manufactured that vacuum tubes are located in upward position with an angle of one degree. Check the angle of the vacuum tubes using an angle gauge (Figure-16). With this process, the installation of the supporting frame is completed. To assemble the vacuum tubes, follow these considerations:

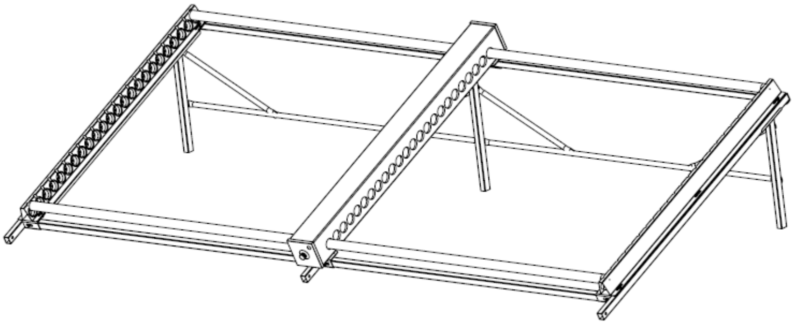
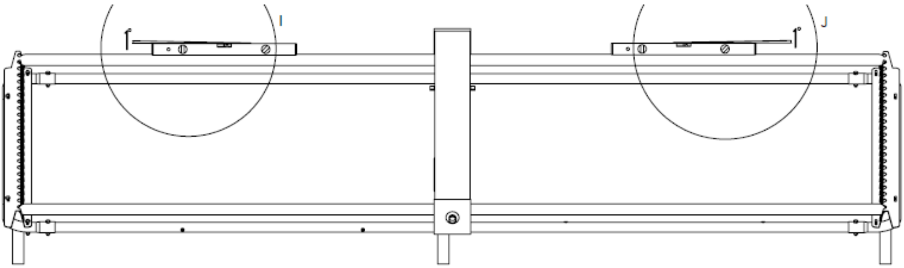
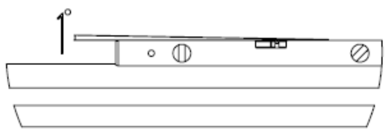


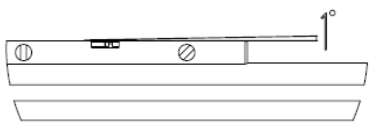
Figure-15. *Checking the manifold using four vacuum tubes whether they are properly placed without any tension*



(a) general view



(b) view I



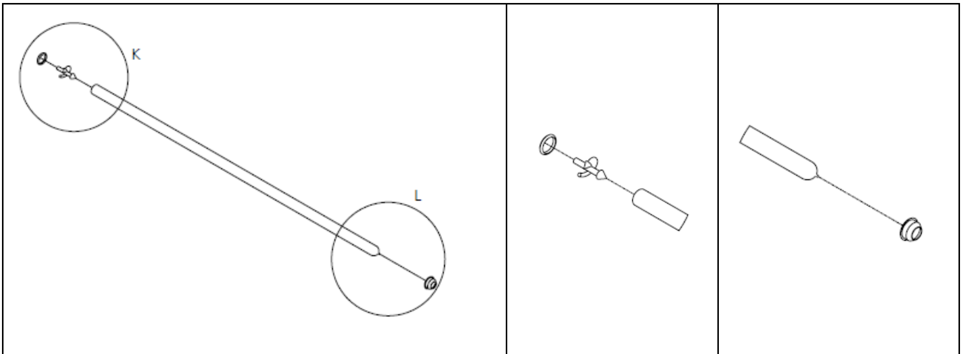
(c) view J

Figure-16. *Checking the angle of the vacuum tubes using an angle gauge*

CONSIDERATIONS DURING THE INSTALLATION OF VACUUM TUBES

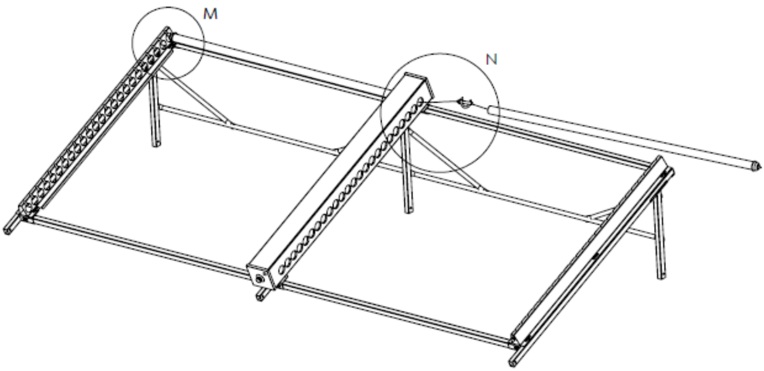
- Keep vacuum tubes in their box until the time of installation.
- During installation, make sure that neither end point of the vacuum tube is impacted. The tip is the most sensitive part of the tubes.
- Be careful when installing vacuum tubes. They can break as a result of shock, bending or falling.

- First place the dust seals to the vacuum tubes (Figure-17).
- Prepare a dishwashing detergent (or liquid soap) and a water mixture as a ratio of one by one in a small bowl. Apply this mixture to just 10 cm part of the open side of vacuum tube. This allows the vacuum tube to be easily installed through the sealing gaskets in the tank. Never use petroleum oil products. The silicone rubber seal wears off immediately.
- When assembling the vacuum tubes to the silicone rubber seal, make gentle circular wrist motions to place it (Figure-18).
- Place the plastic supports in only one side of the bottom holder; let’s say to the left side (Figure-17). Otherwise, width of the collector is not enough to mount the other side.
- Install the tubes to the left side. To install the vacuum tubes to the right side, hold a tube and plastic support together. Align it to its place in the lower holder and locate it.

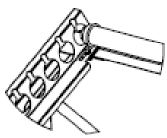


(a) general view	*(b)* view K	*(c)* view L

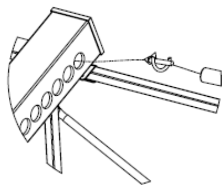
Figure-17. *Placing the plastic supports in the bottom holders and dust seals to the vacuum tubes*



(a) general view



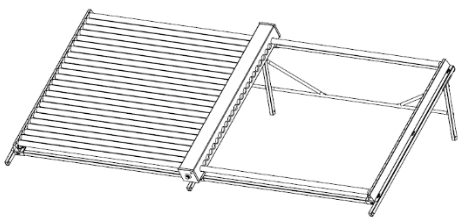
(a) view M



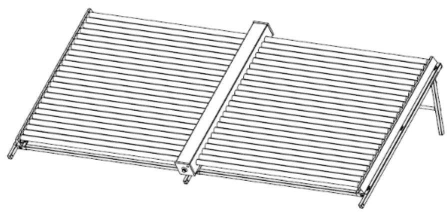
(b) view N

Figure-18. *Assembling the vacuum tubes to the manifold*

Install vacuum tubes first one side and then complete the other side (Figure-19).



(a) left side



(b) right side

Figure-19. *Assembling the vacuum tubes*

Shoes should be used to fix the Miletus Collector to the floor using screws (Figure-20). The shoes are designed to be mounted both on the collector legs and on the floor. Authorized service personnel who install the collector can also fix it to the base by welded joints if required.

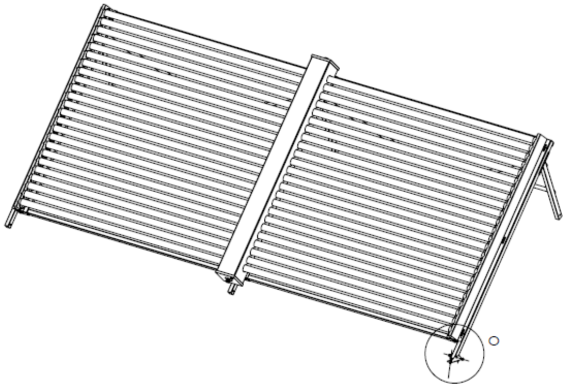
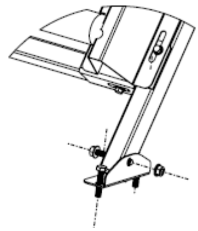
	
(a) general view	*(b) view O*

Figure-20. *Installation of shoes*

After completing the installation, fill in the system with water and check for leaks.
If the vacuum tubes are exposed to heavy sunlight for more than 10 minutes, do not allow to enter cold water into the vacuum tubes because they may crack due to thermal shock. As soon as the system is assembled, it is better to cover the vacuum tubes for preventing against sunlight. However, if they are not covered by a curtain, the system should be filled in with cold water after getting dark. Then, clean the dusty vacuum tubes with glass cleaner etc.

If the instructions described in this manual are not observed, any damages and malfunctions that may occur will be excluded from the warranty.

8.3 HYDRAULIC DIAGRAM

The hydraulic diagram of solar domestic water heater system which is supported by another heater is shown in Figure-21. A closed-loop tank, in which heated water or liquid can be used to heat the usage water using an equipment in the reservoir tank such as double-wall, serpentine and, heat-exchanger, is also used in this hydraulic diagram. According to this diagram, you can check whether all connections are properly made. Main installation equipment of the whole system and some other combinations of the hydraulic diagram are also given in Appendix 2.

CONSIDERATIONS FOR THE INSTALLATION OF THE HYDRAULIC SYSTEM
It is recommended to install a (ball) valve to the inlet and outlet of each manifold. They are necessary to shut off the water for repair or renovation. As in the manifold,

it is also recommended to place a (ball) valve in the inlet and outlet of the pump. If the pump breaks or if the dirt prevents circulation, they are necessary to repair and clean the pump. In addition, locate a strainer to the upstream of the pump (away from the pump) and a check valve to the downstream of the pump (towards the pump) to protect it.

For the hydraulic system, proper pipe diameter must be calculated and selected for each connection to increase the performance of the collector. Polymer or metal pipes can be used depending on the application. Usually, PPR-C pipe is preferred for cold water inlet to the manifold because it is easy to install and lifecycle of it is long. On the other hand, either galvanized steel or PPR-C pipe is preferred in the hot water outlet of the manifold. If PPR-C pipe is used, supports should be placed at certain intervals so that the pipe does not bend due to hot water effect. When galvanized steel pipe is used, supports must also be placed at certain intervals because the nipple in the hot water outlet of the manifold does not have enough strength to carry the steel pipe. Another important point is that hot water pipe line must be installed above the level of hot water outlet nipple. Otherwise, it causes air accumulation at the elbow part and the performance of the system is affected.

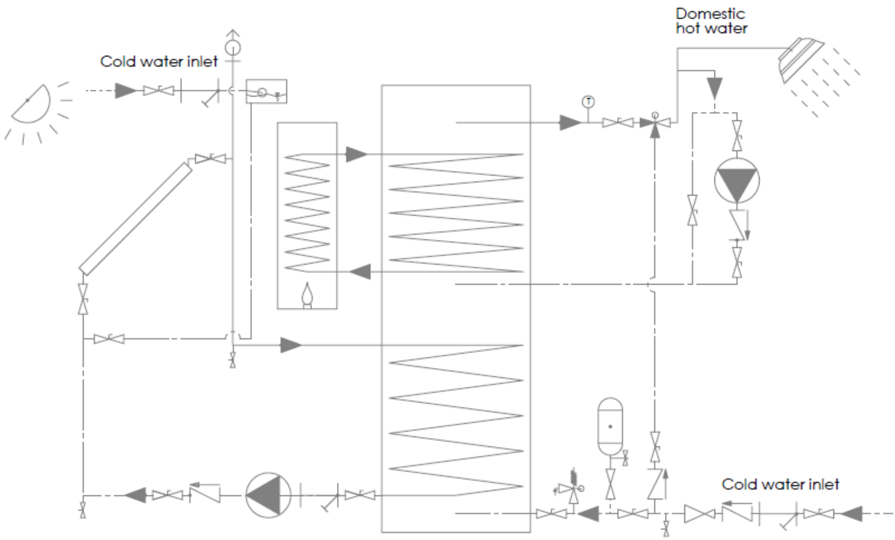


Figure-21. *Hydraulic diagram of the system- closed-loop solar domestic water heater supported by auxiliary heater.*

A vent line must be installed because the hydraulic system is unpressurized. The vent line provides room for expansion when collectors are not in use. Using T pipe connection, a vent line can be installed to the hot water pipe line.

If number of manifolds are connected in parallel position, place a vent line to each collector or every 2 collectors for expansion because each manifold contains 82 liters of water. This is a very large amount of water for a single ventilation in a multi-manifold system. Insufficient ventilation causes pressure increase in the hydraulic system due to thermal expansion of water. Then, because of pressure increase, vacuum tubes can be dislocated from their position and as a result of it they can fall down and break.

8.4 ELECTRIC HEATER

There is no any electric heater or any place for it in Miletus collector. If it is needed, electric heater(s) can be installed into the water tank.

8.5 MAGNESIUM ANODE

Although there is no magnesium anode rod in the manifold, it is recommended to use in hydraulic system. This may be necessary especially when it is used in an open-loop application because fresh water carries much more oxygen. In addition, manifold is made of 304 austenitic stainless steel. Therefore, if chloride level is high in the water such as swimming pool heating application, do not heat the water above 50^{o}C because chloride in gas form can penetrate the manifold in a few months. Another solution for this is that it can be used as closed-loop system. Moreover, when it is not used in the summer, drain the water to protect it.

8.6 RUBBER SEALS IN WATER TANK

The sealing between the vacuum tubes and the tank is provided by silicone rubber gaskets in the solar water heater. It is recommended to replace the gaskets every 4-6 years. You can continue to use it if there is no leakage from any gaskets but in this case occasionally check for any leaks.

9. TEST, CONTROL, USAGE, MAINTENANCE AND TROUBLESHOOTING

Before starting to use the collector, control the checklist indicated in Table-4 and test the system.

USAGE AND MAINTENANCE

- If you do not use solar water heater for a long term (due to holiday or similar reasons), it is advised to cover the vacuum tubes with a non-transparent cover. In this way, the system is prevented staying at high temperature. So the life of the system may be longer.
- Do not turn off the circulation pump for a long term. Especially during the summer when the water temperature in the manifold rises above 90^oC, it is necessary to enter cold water in the manifold to protect the system. Another solution is when it is not used in summer, drain the water to protect it. Then, if the tubes are not covered by a curtain, refilling process with water must be done after getting dark.
- This collector does not require any maintenance under normal conditions. However, the system equipment needs to be checked at regular intervals. If necessary, contact the authorized service.
- Check the vacuum tubes regularly. If it is dusty or dirty, clean it. This will make the collector to work more efficiently. Rain is usually enough to keep the tubes clean.
- Do not take any installation and maintenance services from persons other than authorized service personnel.
- No anti-freeze fluid is required against frost.
- Where the water hardness is high, it is recommended to operate the collector system as closed-loop.
- If chloride level is high in the water such as swimming pool heating application, do not heat the water above 50^oC to protect the system. Another solution for this is that it can be used as closed-loop system. Moreover, when it is not used in the summer, drain the water to protect it.
- This system must not be used with seawater. If well, stream or similar kinds of water is used, the water must be analyzed. Excessive lime or chemicals in water may damage the system. A strainer must also be installed to the cold water inlet to protect the pump, etc.
- Do not connect any satellite antenna or etc. to the package system.
- If you are using another type of water heater system such as electric water heater or combi boiler in addition to this system, turn off the hot water inlet valve which goes to the taps from the system you are not using. This problem can be solved by placing a check valve at the hot water outlet.

Table-4. *Post-installation checklist of the solar water heater.*

CONTROL LIST	Check
Installation	
Is the installation according to the instructions and local authority regulations?	
Has the installation been carried out on the roof according to the local regulations?	
Has the system been mounted in an ideal location and at appropriate angle to get sunlight?	
Are all bolts, nuts and other fasteners checked for tightness?	
Have the supports been placed at certain intervals for the hot water pipe line to prevent bending in the line and breakage of the nipple in the hot water outlet of the manifold?	
Has the hot water pipe line been installed above the level of hot water outlet nipple to prevent air accumulation?	
Pipe Connections and Vacuum Tube Assembly	
Have all the pipes properly been installed and insulated?	
Have the vacuum tubes been installed as described in this manual?	
Are there any leaks in the connections or in the vacuum tubes? Recheck again about 30 minutes after the first check.	
Hydraulic Connections:	
Have all the hydraulic connections been carried out?	
Electric Connections	
Has the electric connection been done according to the local regulations?	
General Info	
Was the proper selection of the model and its size made according to the needs of the client?	
Was the selected model suitable for usage water?	
Was the guarantee properly filled in and given to the client?	
Was this user manual given to the client?	

TROUBLESHOOTING

Table-5. *Detection of failures in the system and troubleshooting.*

DETECTION OF FAILURE	CAUSE OF THE PROBLEM	TROUBLESHOOTING
Leakage in the pipe connections	Problem at pipe connections	contact the authorized service
System working at low efficiency	Leakage in connection pipes	Tighten connections
	Vacuum tubes dusty	Clean vacuum tube surfaces
	Excessive hot water consumption compared to the capacity of the system	System is not adequate. Larger system required[1]
	Filters in the system clogged	Check and clean all the filters in the system[1]
Breakage of vacuum tubes	External factors	contact the authorized service
	improper installation of the manifold	contact the authorized service
Leakage in the manifold except pipe connections	Problem in the sealing gaskets of the manifold	Check and change the sealing gaskets[1]
	Failure in the manifold due to high chloride level in the water.	Check and change the manifold[1]

[1]Contact the authorized service

APPENDIX

APPENDIX-1

AUTHORIZED SERVICES & MANUFACTURER

MANUFACTURER:

Title: SİSTEM ENERJİ ÜRETİM SAN ve TİC LTD ŞTİ
Address: Organize Sanayi Bölgesi 8 Sk No 17 Nazilli, Aydin / Turkey
Telephone: +90 (256) 316 2003
Fax: +90 (256) 316 2002
export@sistemtubular.com
teknikservis@sistemtubular.com
http://www.sistemtubular.com/

Note: *Sistem Tubular reserves the right to make any changes on this catalog due to innovations or renovations on the product models and similar reasons. The date of revision is given on the first page.*

APPENDIX-2

HYDRAULIC DIAGRAMS

Main installation equipment and components of hydraulic diagrams are given in Figure-A.1 & 2.

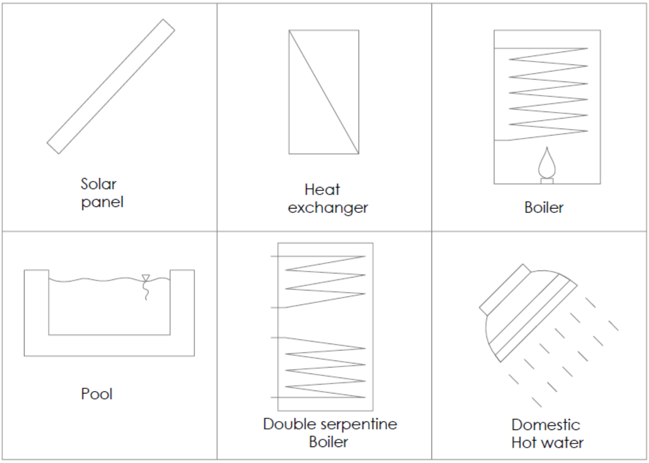


Figure-A.1. *Main installation equipment of hydraulic diagrams.*

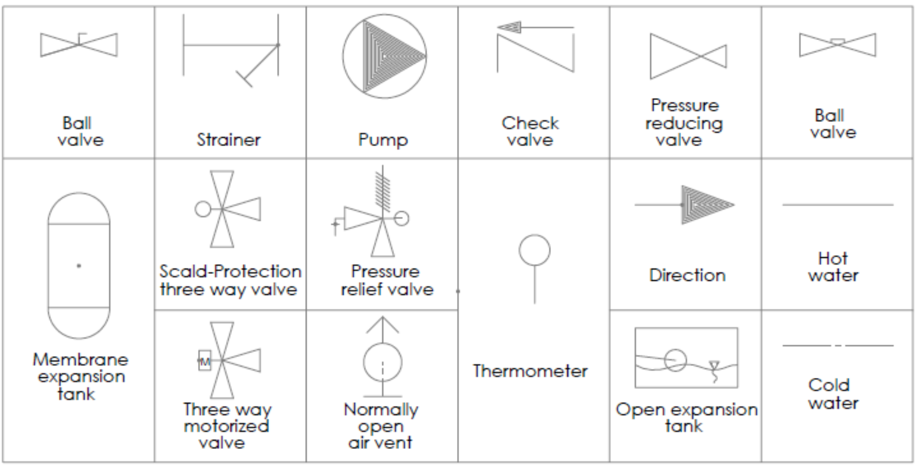


Figure-A.2. *Installation equipment and components of hydraulic diagrams.*

In addition to Figure-28, some other combinations of the hydraulic diagrams are shown in Figure-A.3 - 8.

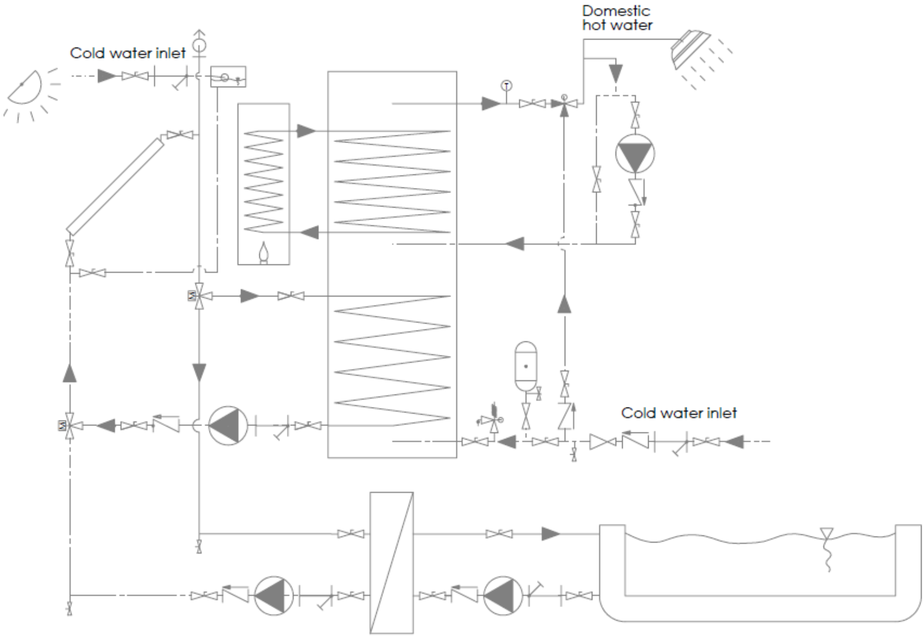


Figure-A.3. *The hydraulic diagram- closed-loop solar domestic water and swimming pool heater supported by auxiliary heater.*

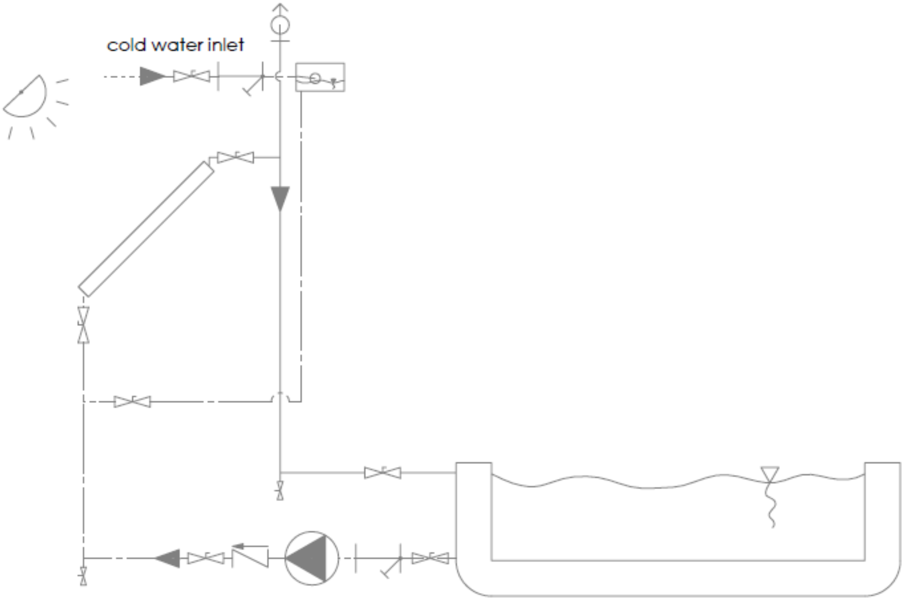


Figure-A.4. *The hydraulic diagram- open-loop solar swimming pool heater.*

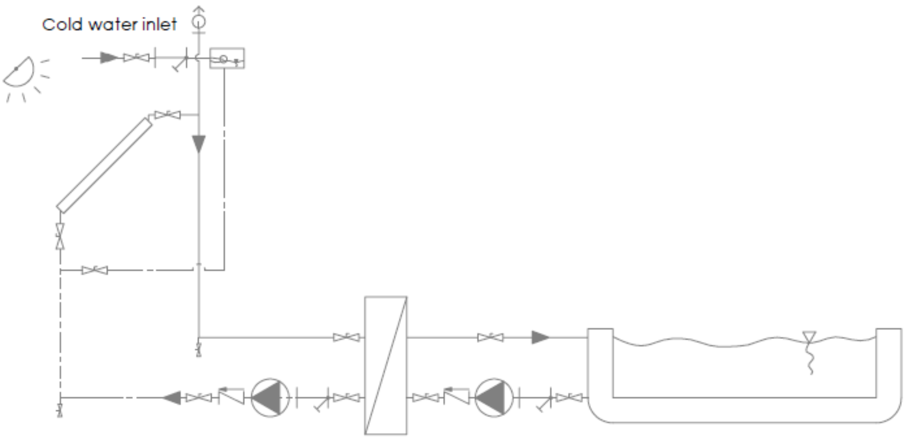


Figure-A.5. *The hydraulic diagram- closed-loop solar swimming pool heater.*

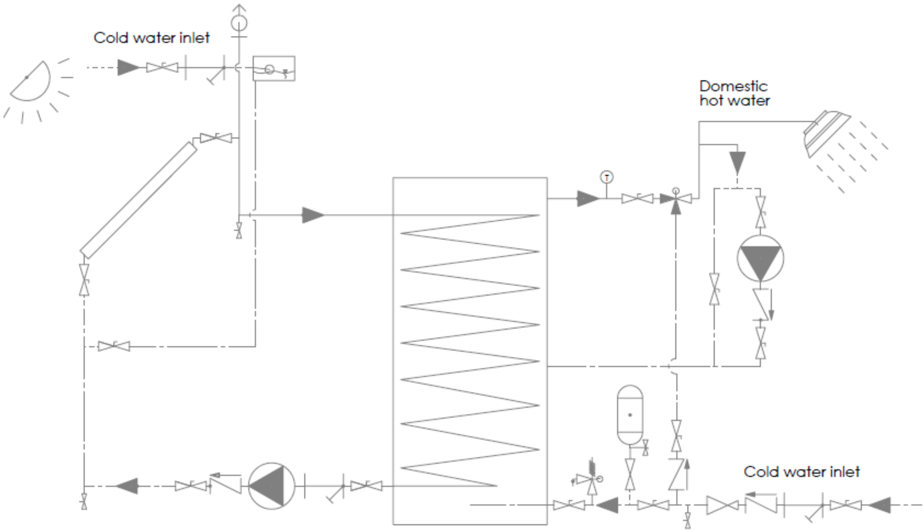


Figure-A.6. *The hydraulic diagram- closed-loop solar domestic water heater.*

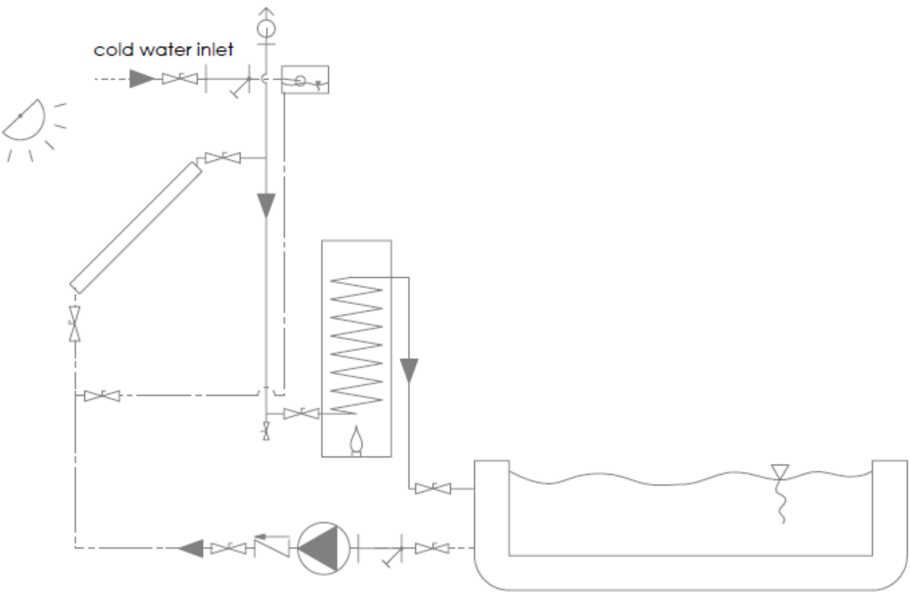


Figure-A.7. *The hydraulic diagram- open-loop solar swimming pool heater supported by auxiliary heater.*

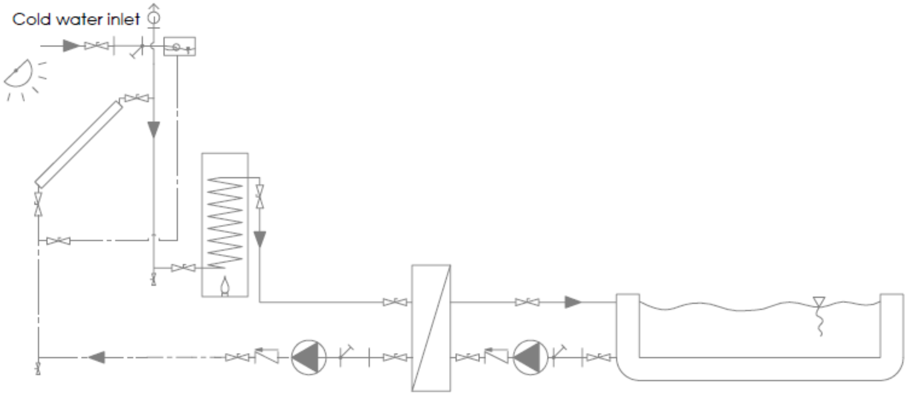


Figure-A.8. *The hydraulic diagram- closed-loop solar swimming pool heater supported by another heater.*

APPENDIX-3

COLLECTOR PERFORMANCE, DETERMINATION OF SYSTEM FLOW RATE, PRESSURE DROP RATIO, AND PUMP SELECTION

A3-1. COLLECTOR PERFORMANCE DEPENDING ON WEATHER CONDITIONS

The most important factor affecting the performance of the collector is the amount of solar radiation received during a day. In addition, weather conditions are important in terms of collector heat losses. As given in Figure-1, the absorber surface area of Miletus collector is 3.12 m^2 and the aperture area is 3.68 m^2. Heat energy graph is given in Mega-joule in Figure-A.9 for a collector as the values of different solar radiation, H, (kW.h/ m^2.day) per m^2 per day. As a reminder, please keep in mind that 1 kW.hour is equal to 3.6 Mega-joules. The values given in the graph can also be calculated using equation A.1.

$$Q = A_1(3.6)H - A_2(T_{collector} - T_{ambient}) \quad (A.1)$$

in this formula where
Q: heat (Mega-Joule)
H: solar radiation per m^2 per day (kW.h/m^2.day). It is multiplied by 3.6 in the formula to convert the unit of heat to M-joule /m^2.day.
$T_{collector}$: temperature of collector fluid (^oC)
$T_{ambient}$: ambient temperature (^oC)
A_1: it is the first constant calculated for Miletus collector = 2.898 m^2
A_2: it is the second constant calculated for Miletus collector = 0.245 M-joule/day. ^oC

Ambient temperature should be taken as the daily average temperature between sunrise and sun set.

> ***Example A1:*** *the amount of solar radiation per m^2 per day is H = 5 kW.h/m^2.day. Evaluate the performance of the manifold as daily heat using the graph in Figure-A.9 or calculate using equation A.1 when the initial water temperature in the manifold is 50^{o}C and the daytime average ambient temperature is 10^{o}C.*
>
> ***Answer:*** *when Delta T = 50 – 10 = 40^{o}C, and H = 5 kW.h/m^2.day, daily heat gain of the manifold is Q = 42.36 Mjoules/day. This value is converted to kW.h/day if divided by 3.6.*

Either using the graph or formula to calculate, you can decide how many manifolds in the system have to be used depending on your needs, taking into account the climate and weather conditions of your region.

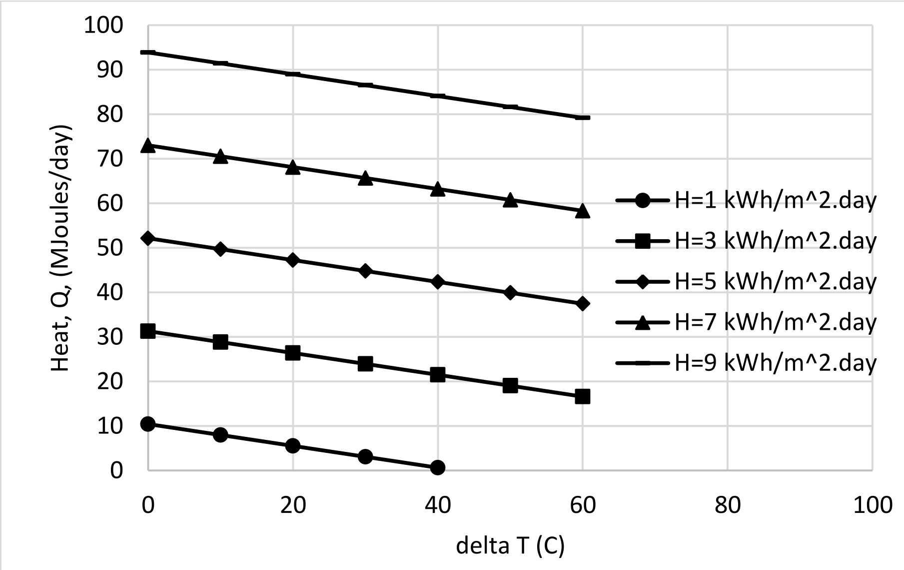


Figure-A.9. *Heat energy graph of the collector depending on ambient and collector fluid temperature.*

A3-2. DETERMINING THE FLOW RATE IN A COLLECTOR SYSTEM

In physics and engineering, the flow rate of a liquid is a measure of the volume of liquid that moves in a certain amount of time. The flow rate can be determined as

$$Q_f = Av \qquad \text{(A.2)}$$

where

Q_f: liquid flow rate (m^3/s or lt/s)

A: area of the pipe or channel (m^2)

V: velocity of the liquid (m/s)

Moreover, mass flow rate is the mass of a substance which passes per unit of time. Its unit is kilogram per second or kg/min in SI units. For water, it can be also used lt/min instead of kg/min. The common symbol is m-dot, ṁ.

$$\dot{m} = \rho v A \qquad (A.3)$$

where
A: area of the pipe or channel (m^2)
v: velocity of the liquid (m/s or m/min)
ρ: density of the fluid (kg/m^3)

Collector systems can be operated with different flow rates depending on the application and the size of the system. The unit of the flow rate is liter/hour.m^2. The reference variable to choose the appropriate flow rate is the absorber area.

A higher flow rate selected per m^2 collector area means a lower temperature spread in the collector circuit at the same collector output. In other words, a lower flow rate per m^2 collector area means a higher temperature spread in collector system. The average collector temperature increases and the collector efficiency decreases with a high temperature spread (or low flow rate). Nevertheless, lower flow rate in the system means less auxiliary energy expended for operating the pump and in this case, smaller cross section area in connection lines are possible.

What is the right operating flow rate?
The flow rate for safe engineering application must be high enough to ensure a reliable and even flow through the entire array. The optimum value for flat-plate and vacuum tube collectors with heat pipes is 25 lt/h.m^2 at 100 percent pump rate because the pipe line goes straight. However, when direct flow vacuum tube collectors with individual tubes linked in parallel within the collector is used, the flow rate must be at least 40 l/h.m^2. In other words, minimum flow rate must be selected as 40 lt/h.m^2 to prevent any air bubble formation in turning points as in S lines. A matched flow operation is not recommended for this type of collector as this would put at risk the even internal flow through the collector as a whole. In this Miletus collector system, it is recommended to **take the flow rate about 60 lt/h.m^2** as optimum value.

The recommended flow velocity lies between 0.4 and 0.7 m/s subject to the flow rate and pipe dimension. This flow velocity range represents a good compromise between pressure drop and ventilation. Venting the solar circuit is more difficult by oversized pipes contrary to the heating circuit. When the flow is in downward direction or pipes are in S formation, the air bubbles have to move downwards together with the fluid, not upwards.

Recommended pipe diameters marked are given in Table-A.1 for PPRC pipes manufactured according to PN20 nominal pressure rating standard. Miletus is an unpressurized collector which circulates water using a pump. Therefore, it is also possible to use PN10 pressure class PPRC pipes. In this case, the flow velocity decreases as the pipe thickness is thinner. In general, it is better to use PN20 pressure class PPRC pipes to minimize bending due to hot water effect and to ensure longer life of the pipeline.

If you require to use galvanized steel pipe in the circuit line, recommended pipe diameters marked are given in Table-A.2 for medium galvanized steel pipes.

Example A2: *a system with six Miletus collectors will be installed. Absorber area of each collector is 3.12 m^2. In other words, total absorber area is 18.72 m^2. Recommended flow rate is 60 lt/h.m^2 which has a throughput of 1123 lt/h. This value must be reached at maximum pump rate (100%). Find appropriate pipe dimension and flow velocity to adjust the output stage of the pump and complete the initial selection for it.*

Answer: *flow rate is 60 lt/h.m^2 which has a throughput of 1123 lt/h = 18.72 lt/min for six collectors. Using Table-A.1 and Table-A.2, the following pipe dimensions and flow velocities are found. Any of these values can be selected:*
-For PPRC pipe, DN40, ID= 26.6mm with a flow velocity of 0.56 m/s.
-For PPRC pipe, DN50, ID=33.4mm with a flow velocity of 0.36 m/s.
-For medium galvanized steel pipe, DN25, ID=27.3mm with a flow velocity of 0.53 m/s.

Table-A.1. *Flow velocity and required pipe dimensions for PPRC pipes manufactured according to PN20.*

# of Manifold or collector	Absorber area (m^2)	Flow rate l/min	Flow velocity (m/s) for pipe dimensions							
			DN20* ID= 13,2	DN25 ID= 16,6	DN32 ID= 21,2	DN40 ID= 26,6	DN50 ID= 33,4	DN63 ID= 42	DN75 ID= 50	DN90 ID= 60
1	3,12	3,12	0,38	0,24	0,15	0,09	0,06	0,04	0,03	0,02
2	6,24	6,24	0,76	0,48	0,29	0,19	0,12	0,08	0,05	0,04
3	9,36	9,36	1,14	0,72	0,44	0,28	0,18	0,11	0,08	0,06
4	12,5	12,5	1,52	0,96	0,59	0,37	0,24	0,15	0,11	0,07
5	15,6	15,6	1,90	1,20	0,74	0,47	0,30	0,19	0,13	0,09
6	18,7	18,7	2,28	1,44	0,88	0,56	0,36	0,23	0,16	0,11
7	21,8	21,8	2,66	1,68	1,03	0,66	0,42	0,26	0,19	0,13
8	25,0	25,0	3,04	1,92	1,18	0,75	0,48	0,30	0,21	0,15
9	28,1	28,1	3,42	2,16	1,33	0,84	0,53	0,34	0,24	0,17
10	31,2	31,2	3,80	2,40	1,47	0,94	0,59	0,38	0,26	0,18
11	34,3	34,3	4,18	2,64	1,62	1,03	0,65	0,41	0,29	0,20
12	37,4	37,4	4,56	2,88	1,77	1,12	0,71	0,45	0,32	0,22
13	40,6	40,6	4,94	3,13	1,92	1,22	0,77	0,49	0,34	0,24
14	43,7	43,7	5,32	3,37	2,06	1,31	0,83	0,53	0,37	0,26
15	46,8	46,8	5,70	3,61	2,21	1,40	0,89	0,56	0,40	0,28
16	49,9	49,9	6,08	3,85	2,36	1,50	0,95	0,60	0,42	0,29
17	53,0	53,0	6,46	4,09	2,51	1,59	1,01	0,64	0,45	0,31
18	56,2	56,2	6,84	4,33	2,65	1,69	1,07	0,68	0,48	0,33
19	59,3	59,3	7,22	4,57	2,80	1,78	1,13	0,71	0,50	0,35
20	62,4	62,4	7,60	4,81	2,95	1,87	1,19	0,75	0,53	0,37
25	78,0	78,0	9,50	6,01	3,68	2,34	1,48	0,94	0,66	0,46
30	93,6	93,6	11,4	7,21	4,42	2,81	1,78	1,13	0,79	0,55
35	109	109	13,3	8,41	5,16	3,28	2,08	1,31	0,93	0,64
40	125	125	15,2	9,62	5,90	3,74	2,38	1,50	1,06	0,74

*In PPRC pipes, outer diameter (OD) is equal to the standard's number. e.g. OD=20mm for DN20. Pipe diameters are in mm.

Table-A.2. *Flow velocity and required pipe dimensions for medium galvanized steel pipes.*

# of Manifold or collector	Absorber area (m^2)	Flow rate l/min	Flow velocity (m/s) for pipe dimensions						
			DN15* OD= 21,3 ID=16,1	DN20 OD= 26,9 ID=21,7	DN25 OD= 33,7 ID=27,3	DN32 OD= 42,4 ID=36	DN40 OD= 48,3 ID=41,9	DN50 OD= 60,3 ID=53,1	DN65 OD= 76,1 ID=68,9
1	3,12	3,12	0,26	0,14	0,09	0,05	0,04	0,02	0,01
2	6,24	6,24	0,51	0,28	0,18	0,10	0,08	0,05	0,03
3	9,36	9,36	0,77	0,42	0,27	0,15	0,11	0,07	0,04
4	12,5	12,5	1,02	0,56	0,36	0,20	0,15	0,09	0,06
5	15,6	15,6	1,28	0,70	0,44	0,26	0,19	0,12	0,07
6	18,7	18,7	1,53	0,84	0,53	0,31	0,23	0,14	0,08
7	21,8	21,8	1,79	0,98	0,62	0,36	0,26	0,16	0,10
8	25,0	25,0	2,04	1,13	0,71	0,41	0,30	0,19	0,11
9	28,1	28,1	2,30	1,27	0,80	0,46	0,34	0,21	0,13
10	31,2	31,2	2,56	1,41	0,89	0,51	0,38	0,23	0,14
11	34,3	34,3	2,81	1,55	0,98	0,56	0,42	0,26	0,15
12	37,4	37,4	3,07	1,69	1,07	0,61	0,45	0,28	0,17
13	40,6	40,6	3,32	1,83	1,16	0,66	0,49	0,31	0,18
14	43,7	43,7	3,58	1,97	1,24	0,72	0,53	0,33	0,20
15	46,8	46,8	3,83	2,11	1,33	0,77	0,57	0,35	0,21
16	49,9	49,9	4,09	2,25	1,42	0,82	0,60	0,38	0,22
17	53,0	53,0	4,34	2,39	1,51	0,87	0,64	0,40	0,24
18	56,2	56,2	4,60	2,53	1,60	0,92	0,68	0,42	0,25
19	59,3	59,3	4,86	2,67	1,69	0,97	0,72	0,45	0,27
20	62,4	62,4	5,11	2,81	1,78	1,02	0,75	0,47	0,28
25	78,0	78,0	6,39	3,52	2,22	1,28	0,94	0,59	0,35
30	93,6	93,6	7,67	4,22	2,67	1,53	1,13	0,70	0,42
35	109	109	8,94	4,92	3,11	1,79	1,32	0,82	0,49
40	125	125	10,22	5,63	3,56	2,04	1,51	0,94	0,56

*Outer diameter (OD), inner diameter (ID). Pipe diameters are in mm.

A3-3. PRESSURE DROP RATIOS

PRESSURE DROP IN COLLECTORS

Pressure drop occurs in collectors like the other hydraulic components. When the collectors are linked in series, the total pressure drop is equal to the total of all individual pressure drop values. On the other hand, when they are linked in parallel, the total pressure drop is equal to the pressure drop of one single collector. To get this conclusion, it is assumed that all collectors are in the same size, the average collector temperature is identical and, the efficiency is almost equal.

Experimentally measured collector pressure drop is given in Figure-A.10. Using the polynomial curve fitting line and formula for it, pressure drop in the collector can be calculated.

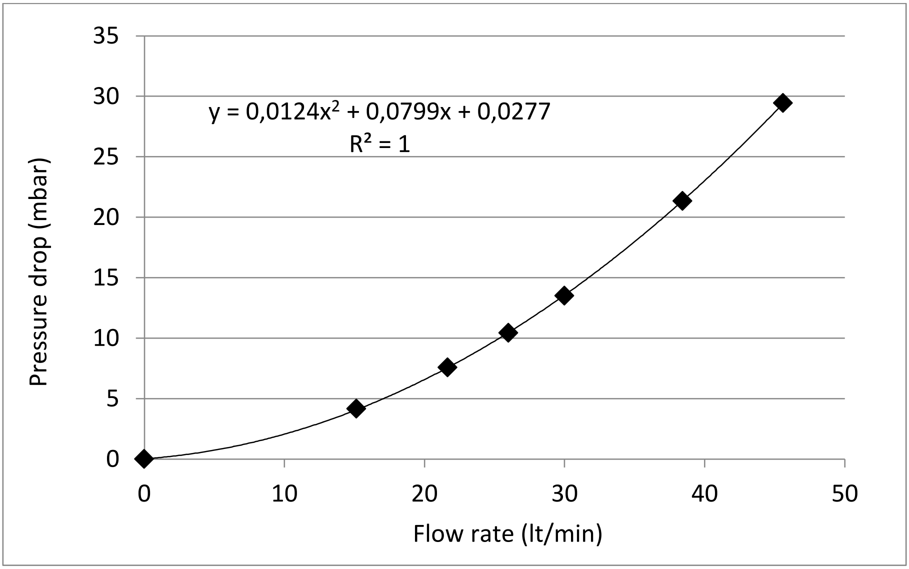
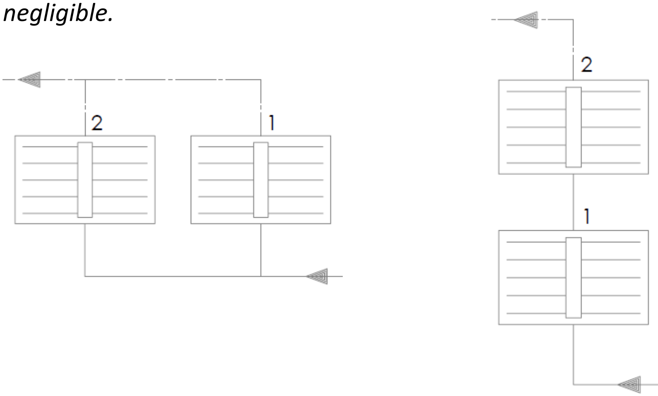


Figure-A.10. *Experimentally measured collector pressure drop and polynomial curve fitting line of the data.*

Example A3: *a system with two Miletus collectors will be installed. Absorber area of each collector is 3.12 m^2. In other words, total absorber area is 6.24 m^2. Recommended flow rate is 60 lt/h.m^2 which has a throughput of 374.4 lt/h. Determine the pressure drop of the collectors linked in parallel and series.*

If two collectors are linked in parallel, then the throughput per collector is half of the flow rate, 374.4/2 = 187.2 lt/h = 3.12 lt/min (Figure-A.11). Using the formula in Figure-A.10, pressure drop in millibar can be calculated and it is 0.4 mbars, almost negligible.



(a) (b)

Figure-A.11. *Determining the pressure drop of 2 collectors linked in (a) parallel and (b) series.*

If the collectors are linked in series, the throughput per collector is equal to 374.4 lt/h = 6.24 lt/min. Using Figure-A.10, the calculated individual pressure drop of a single collector is 1 mbar. The pressure drop values are added up for each collector. Then total pressure drop is 2 mbars for the complete collector array.

In both cases, it is assumed that all collectors are in the same size, the average collector temperature is identical and the efficiency is almost equal.

In addition to the main circuit pipe diameters which are selected using Table-A.1 and Table-A.2, collector input and output pipe diameters should be selected according to the flow rate of individual collector as described in this example.

PRESSURE DROP IN PIPE LINES

Pressure drop in pipelines can be calculated using many different approaches and formulas. Also, there are some ready programs prepared by pipe manufacturers on the internet to calculate it. Although there are many effective factors for pressure drop in a pipe circuit, such as operating temperature, medium or type of liquid, number of bends or elbows, valves, filters, pressure drop per meter pipework in mbar/m are shown in Table-A.3 and Table-A.4 for PPRC pipes and medium grade galvanized steel pipes, respectively. It is assumed that the operating temperature is at 60^{o}C to minimize temperature effect in the pressure drop. The values are calculated for the pipes and other components in pipe line at only 60^{o}C because in this case, the temperature effect is limited to about maximum 3%. The following values are also used for water at 60^{o}C; dynamic viscosity is equal to 466(10^{6}) N.s/m^{2} and density of water is equal to 983kg/m^{3}. In general, surface roughness of PPRC pipe and galvanized steel pipe is taken as 0.0015 and 0.15 respectively.

Table-A.3. *Pressure drop and required pipe dimensions for PN20 PPRC pipes.*

# of Manifold or collector	Flow rate l/min	Pressure drop per metre pipework in mbar/m							
		DN20 ID= 13,2	DN25 ID= 16,6	DN32 ID= 21,2	DN40 ID= 26,6	DN50 ID= 33,4	DN63 ID= 42	DN75 ID= 50	DN90 ID= 60
1	3,12	1,65							
2	6,24	5,54	1,86						
3	9,36		3,80	1,18					
4	12,5			1,97	0,67				
5	15,6			2,92	0,99				
6	18,7				1,36	0,46			
7	21,8				1,78	0,60			
8	25,0				2,28	0,77			
9	28,1					0,94			
10	31,2					1,13	0,38		
11	34,3					1,34	0,45		
12	37,4					1,57	0,52		
13	40,6						0,61		
14	43,7						0,69	0,30	
15	46,8						0,78	0,34	
16	49,9						0,87	0,38	
17	53,0						0,97	0,42	
18	56,2						1,08	0,47	
19	59,3						1,19	0,52	0,22
20	62,4						1,30	0,57	0,24
25	78,0							0,84	0,35
30	93,6								0,49
35	109								0,64
40	125								0,82

Table-A.4. *Pressure drop and required pipe dimensions for medium galvanized steel pipes.*

# of Manifold or collector	Flow rate l/min	Pressure drop per metre pipework in mbar/m						
		DN15 OD= 21,3 ID=16,1	DN20 OD= 26,9 ID=21,7	DN25 OD= 33,7 ID=27,3	DN32 OD= 42,4 ID=36	DN40 OD= 48,3 ID=41,9	DN50 OD= 60,3 ID=53,1	DN65 OD= 76,1 ID=68,9
1	3,12	0,86						
2	6,24	3,21						
3	9,36		1,49					
4	12,5		2,61	0,80				
5	15,6		4,00	1,22				
6	18,7			1,73				
7	21,8			2,33	0,56			
8	25,0			3,03	0,73			
9	28,1				0,91			
10	31,2				1,11	0,51		
11	34,3				1,34	0,61		
12	37,4				1,58	0,72		
13	40,6				0,66	0,85		
14	43,7				2,14	0,98		
15	46,8					1,11	0,33	
16	49,9					1,26	0,37	
17	53,0					1,42	0,42	
18	56,2					1,59	0,47	
19	59,3					1,76	0,52	
20	62,4					1,95	0,57	
25	78,0						0,88	0,23
30	93,6						1,26	0,33
35	109							0,44
40	125							0,58

PRESSURE DROP FOR DIFFERENT FACTORS

As explained in the section of "Pressure Drop in Pipelines", it is assumed that the operating temperature is at 60°C to minimize temperature effect in the pressure drop of the entire pipe circuit. The given values in Table-A.5 and Table-A.6 are constants which are described to simplify the process. Multiply these constants by the selected values from Table A-3 and/or Table A-4 for each application.

Pipe entrance: to describe the pressure drop, use the constant given in Table-A.5 or A.6 in case of tank-to-pipe entry or similar applications. Multiply the constant by the selected value given in Table-A.3 or A.4.

Sudden contraction of the pipe diameter: After selecting the pressure drop in the pipeline from Table-A.3 or A.4, multiply by the corresponding constant in Table-A.5 or A.6 for each contraction of the pipe diameter.

Sudden enlargement of the pipe diameter: After selecting the pressure drop in the pipeline from Table-A.3 or A.4, multiply by the corresponding constant in Table-A.5 or A.6 for each enlargement of the pipe diameter.

Bend (Elbow): take into account the constant given in Table-A.5 or A.6 to calculate the pressure drop for each elbow connection used in the pipeline

Check valve: use the **c**onstant given in Table-A.5 or A.6 to consider the pressure drop for each check valve.

T connection: the pressure drop constant in a sharp edged T connection is also given in Table-A.5 or A.6 for each pipe dimension.

Strainer: the pressure drop constant in a Y-strainer is also given in Table-A.5 or A.6 for each pipe dimension.

Table-A.5. *Other effective factors in pressure drop for PN20 PPRC pipes.*

Pressure drop factors	Multiply this constant by the selected value from Table A-3 for each application							
	DN20 ID= 13,2	DN25 ID= 16,6	DN32 ID= 21,2	DN40 ID= 26,6	DN50 ID= 33,4	DN63 ID= 42	DN75 ID= 50	DN90 ID= 60
Pipe entrance	0,25	0,3	0,4	0,55	0,75	1	1,2	1,5
Sudden contraction, for reduced ID	0,10	0,15	0,20	0,25	0,35	0,40	0,50	---
Sudden enlargement, for larger ID	---	0,20	0,35	0,40	0,50	0,70	0,40	0,60
Bend (elbow)	0,25	0,30	0,40	0,50	0,60	0,75	0,90	1
Check valve	2,2	2,5	2,9	3,4	4	4,8	5,5	6,5
T connection	0,5	0,7	0,9	1,2	1,6	2,1	2,6	3,2
Strainer	1,4	2	2,8	2,8	3,5	5,5	7,2	9,5

Table-A.6. *Other effective factors in pressure drop for medium galvanized steel pipes.*

Pressure drop factors	Multiply this constant by the selected value from Table A-4 for each application						
	DN15 OD= 21,3 ID=16,1	DN20 OD= 26,9 ID=21,7	DN25 OD= 33,7 ID=27,3	DN32 OD= 42,4 ID=36	DN40 OD= 48,3 ID=41,9	DN50 OD= 60,3 ID=53,1	DN65 OD= 76,1 ID=68,9
Pipe entrance	0,20	0.30	0,40	0,60	0,70	1	1,30
Sudden contraction, for reduced ID	0,10	0,15	0,20	0,20	0,35	0,5	---
Sudden enlargement, for larger ID	---	0,40	0,25	0,60	0,20	0,70	1,2
Bend (elbow)	0,30	0,40	0,55	0,75	0,85	1,1	1,5
Check valve	1,55	2	2,4	3	3,45	4,2	5,4
T connection	0,42	0,65	0,85	1,25	1,5	2	2,8
Strainer	1,2	1,9	1,9	2,9	3,9	5,8	9

A3-4. PUMP SELECTION

Direct flow vacuum tube collectors with individual tubes linked in parallel within the collector is used, the minimum flow rate must be selected as 40 lt/h.m^2 to prevent any air bubble formation in the pipeline as explained in section A3.2. It is recommended to **take the flow rate about 60 lt/h.m²** as optimum value in this Miletus collector system. The recommended flow velocity lies between 0.4 and 0.7 m/s subject to the flow rate and pipe dimension. Pressure drop in collectors, pipe lines and other effective factors are determined as explained in section A3-3. Then, these values must be considered to select proper pump size. Commercially available centrifugal pumps are advised to use. The maximum working temperature of the selected pump should be at least 100°C to protect it reliably against over temperature.

A3-5. METHOD OF CALCULATION

(1) Determine how much hot water is needed and the energy to heat it up. Also define required temperature of hot water.
(2) Find the amount of solar radiation per m^2 per day in your region from internet or elsewhere. Select the value for angled collectors. Since the vacuum tubes are installed in horizontal direction, the collector angle almost has no effect on the collector efficiency depending on the seasons or the latitude of the installation location (see section 8.1).
(3) Calculate performance of the collector depending on weather conditions and define the operating temperature of the collector.
(4) Decide how many Miletus collectors are needed and select their installation configurations
(5) Determine the system flow rate and appropriate pipe dimension of the main pipeline. Moreover, evaluate pipe dimension for collector inlet and outlet
(6) Select the appropriate size of hot water tank
(7) Calculate pressure drops in collectors, pipelines, and for different equipment
(8) Using flow rate and pressure drop ratio select a pump

The application of these calculation methods is given in this case study.

CASE STUDY: Hot water consumption application in a hotel.

A hotel's hot water consumption will be supply by Miletus collectors. This apart hotel is in Kusadasi, Turkey and has the accommodation capacity of 70 people. It is assumed that one person consumes 50 lt of hot water daily and the used water temperature is 45 C. Under these conditions, how many Miletus Collectors are needed in order to meet the consumption of hot water based in April? Do all necessary all analyzes.

In Kuşadası, the average daytime maximum temperature is 20°C in April and the minimum average temperature in the night is 10°C. The daytime average temperature is taken as 16^{o}C.

To meet the hot water consumption of the customers in the morning, the starting temperature of the water in the tank is expected to be at least minimum 45^{o}C. Also, the tap water temperature is 15^{o}C.

Accordingly, 70 people use 3500 lt of hot water a day. The temperature difference between the hot water tank and tap water is ΔT=(45-15) = 30 ^{o}C.

Energy required to heat 3500 lt of water = 3500kg(1kcal/kg.C)(30C) = 105 000 kcal. It is assumed 1lt = 1kg of water. To meet 100% of the hot water demand in summer, it would be enough to meet 70% of it in April because the amount of solar radiation per m^2 per day is H = 5.5 kW.h/m^2.day in the region of the hotel, Kusadasi in April and H=7.5 kW.h/m^2.day in summer. This value can be found from internet. In addition, the hotel occupancy percentage is not 100% in April. Therefore, 73 500 kcal /day energy is needed.

when the initial water temperature in the manifold is 45^{o}C and the daytime average ambient temperature is 16^{o}C, the performance of the manifold as daily heat using equation A.1:

$Q = A_1(3,6)H - A_2(T_{collector} - T_{ambient}) = 2.898(3.6)5.5 - 0.245(45\text{-}16)=$
$Q = 50$ *Mjoules/day = 13.89 kW.h/day= 11945 kcal/day*

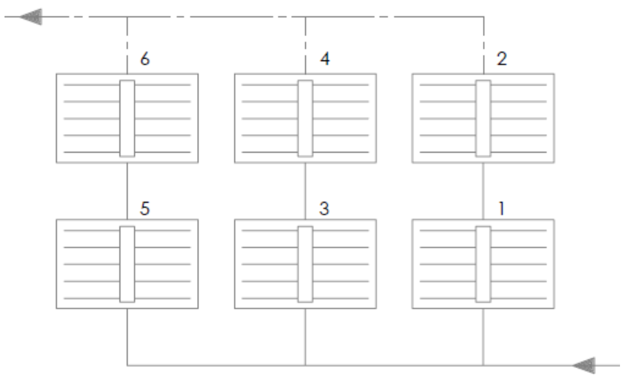


Figure-A.12. *6 collectors linked in parallel and serial lineup.*

73500/11945 = 6.15. Six Miletus collectors are needed and it is decided to link them 3 in parallel and 2 in serial positions as shown in figure-A.12. In case of any problems, it is recommended to place one ball valve at the each collector inlet and outlet to shut off water. Then, you can still continue to use the rest of the system during the repair.

Absorber area of each collector is 3.12 m^2. Recommended flow rate is 60 lt/h.m^2 which has a throughput of 1123 lt/h for 6 collectors. This value must be reached at maximum pump rate (100%). It is assumed that all collectors are in the same size, the average collector temperature is identical and the efficiency is almost equal.

Appropriate pipe dimension and flow velocity to adjust the output stage of the pump can be found as;
flow rate is 60 lt/h.m^2 which has a throughput of 1123 lt/h = 18.72 lt/min for six collectors. Using Table-A.1 and Table-A.2, the following pipe dimensions and flow velocities are found. Any of these values can be selected:
-For PPRC pipe, DN40, ID= 26.6mm with a flow velocity of 0.56 m/s.
-For PPRC pipe, DN50, ID=33.4mm with a flow velocity of 0.36 m/s.
-For medium galvanized steel pipe, DN25, ID=27.3mm with a flow velocity of 0.53 m/s

*The first one, **PN20 DN40 PPRC pipe**, is selected to use in this application.*

As a general rule to choose hot water tank capacity, 80-110 lt water tank should be used per m^2 absorber area in vacuum tube collectors. If the hotel is to be used in 4 seasons, the lower limit should be used. However, if it is to be used seasonally only in summer and spring, the upper limit should be taken. In this case, the water tank per collector is taken as 110 (3.12) = 343.2 lt. Then, the water tank size is 2059.2 lt for 6 collectors. Accordingly, it was decided to use 2000lt of water tank. In general, 250 lt of hot water tank is recommended for 1 Miletus collector used 4 seasons, but about 350 lt of hot water tank is calculated for per collector in this application.

The next step is determining pressure drop ratios:
***Pressure drop in collectors:** Recommended flow rate is 60 lt/h.m^2 which has a throughput of 1123 lt/h for 6 collectors. When 3 collectors are linked in parallel, then the throughput per collector is (1/3)rd of the flow rate, 1123/3 = 374.3 lt/h = 6.24 lt/min. Using the formula in Figure-A.10, pressure drop is 1 mbar. The pressure drop values are not added up for parallel linked collectors.*

When 2 collectors are linked in series to each parallel connection, the throughput per collector is again equal to 374.3 lt/h = 6.24 lt/min. Using Figure-A.10, the calculated individual pressure drop of a single collector is 1 mbar. The pressure drop values are *added up for each serial collector, 2 mbars. Consider only one pipeline and disregard other parallel connections. Then total pressure drop is 2 mbars for the complete collector array.*

Pressure drop in pipe lines: *30 meters PN20 DN40 PPRC pipe are used in the main pipe line. The throughput of it is 1123 lt/h = 18.72 lt/min. Using Table-A.3, pressure drop is 1.36 mbars for per metre pipework. Total pressure drop in the main pipe line becomes 1.36(30) = 40.8 mbars.*

20 meters of pipe is required for the inlet and outlet connections of 6 collectors to the main pipeline. The calculated flow rate was 6.24 lt/min. Using Table-A.1, DN25 for PPRC pipe with a flow velocity of 0.48 m/s is selected. Using Table-A.3, pressure drop is 1.86 mbars for per metre pipework. Total pressure drop in the pipe line for collector connections becomes 1.86(20) = 37.2 mbars.

Pressure drop for different factors:
The constants are taken from Table-A.5 for PN20 DN40 and DN25 PPRC pipes. These constants are multiplied by the selected value from Table A-3 for each application as shown in Table-A.7.

Ball valves are used in the system. Pressure drop can be eliminated in ball valves. However, if another type of valves is used, the pressure drop must be considered.

The pressure drop calculated in Table-A.7 is for an open loop system. If a heat exchanger such as serpentine is used in the collector circuit, pressure drop in it must also be considered and should not exceed a pressure drop of 100 mbars. Ask for it to the tank manufacturer or supplier. Pressure drop of heat exchanger and pressure drops of other effects given in Table-A.7 must be added in the selection of water pump for the heat exchanger system.

Pump selection:
Flow rate is 1123 lt/h = 18.72 lt/min for six collectors and pressure drop is 0.102 bars to select a pump. Again commercially available centrifugal pumps are advised to use. The maximum working temperature of the selected pump should be at least 100^{o}C to protect it reliably against over temperature.

Table-A.7. *Pressure drops for hot water consumption application in a hotel.*

Pressure drop factors	Pressure drop, per metre pipe		Multiplying constant for DN40	Multiplying constant for DN25	Quantity		Calculation	Pressure drop, mbar
6 collectors							1+1	2
Pipe line, DN40	1,36 mbar/m				30m		1,36(30)	40,8
Pipe line, DN25	1,86 mbar/m				20m		1,86(20)	37,2
	DN 40	DN 20			for DN40	for DN25		
Pipe entrance	1,36	1,86	0,55	0,30	1	6	1,36(0,55)1+ 1,86(0,3)6=	4,10
Sudden contraction, for reduced ID	1,36	1,86	0,25	0,15	1		1,36(0,25)1=	0,34
Sudden enlargement, for larger ID	1,36	1,86	0,40	0,20	1	7	1,36(0,40)1+ 1,86(0,20)7=	3,15
Bend (elbow)	1,36	1,86	0,50	0,30	4	2	1,36(0,50)4+ 1,86(0,30)2=	3,84
Check valve	1,36	1,86	3,4	2,5	1		1,36(0,40)1=	0,54
T connection	1,36	1,86	1,2	0,70		4	1,86(0,7)4=	5,21
Strainer	1,36	1,86	2,8	2	1		1,36(2,8)1=	3,81
Total Pressure drop, mbar								101,99