

Design Guide

Solar Thermal Systems



BOSCH

- Solar Collectors**
- DHW Tanks**
- Pump Stations**
- Controls and Accessories**

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1 Principles

1.1 Introduction

Solar thermal systems have become part of modern heating technology and reduce the consumption of fossil fuels. This protects the environment and lowers energy cost.

This technical guide is designed to educate the homeowner, the installer, the engineer, and the architect on solar product offered by Bosch.

It features descriptions of components, system sizing, and piping diagrams.

The installations in this manual have been tried and tested by Bosch and were selected for their simplicity, energy savings, cost effectiveness, and comfort.

1.2 Free solar energy

The energy that is provided by the sun can be used effectively in almost any part of North America. The annual insolation level lies between 2.0 kWh/m²/day (634 BTU/ft²/day) and 7 kWh/m²/day (2,220 BTU/ft²/day). The “insolation map” gives you an idea of the average insolation that can be expected in your region (Figure 1).

A solar thermal system uses the energy of the sun to heat domestic hot water (DHW). Solar

systems for DHW heating are energy-saving and environmentally friendly. Frequently people are unaware of the astounding proportion of heating that technically advanced solar systems can provide today.

A considerable proportion of solar energy can be used for heat generation using solar collector systems, saving valuable fuel, and fewer emissions reduce the burden on the environment and the earth’s climate.

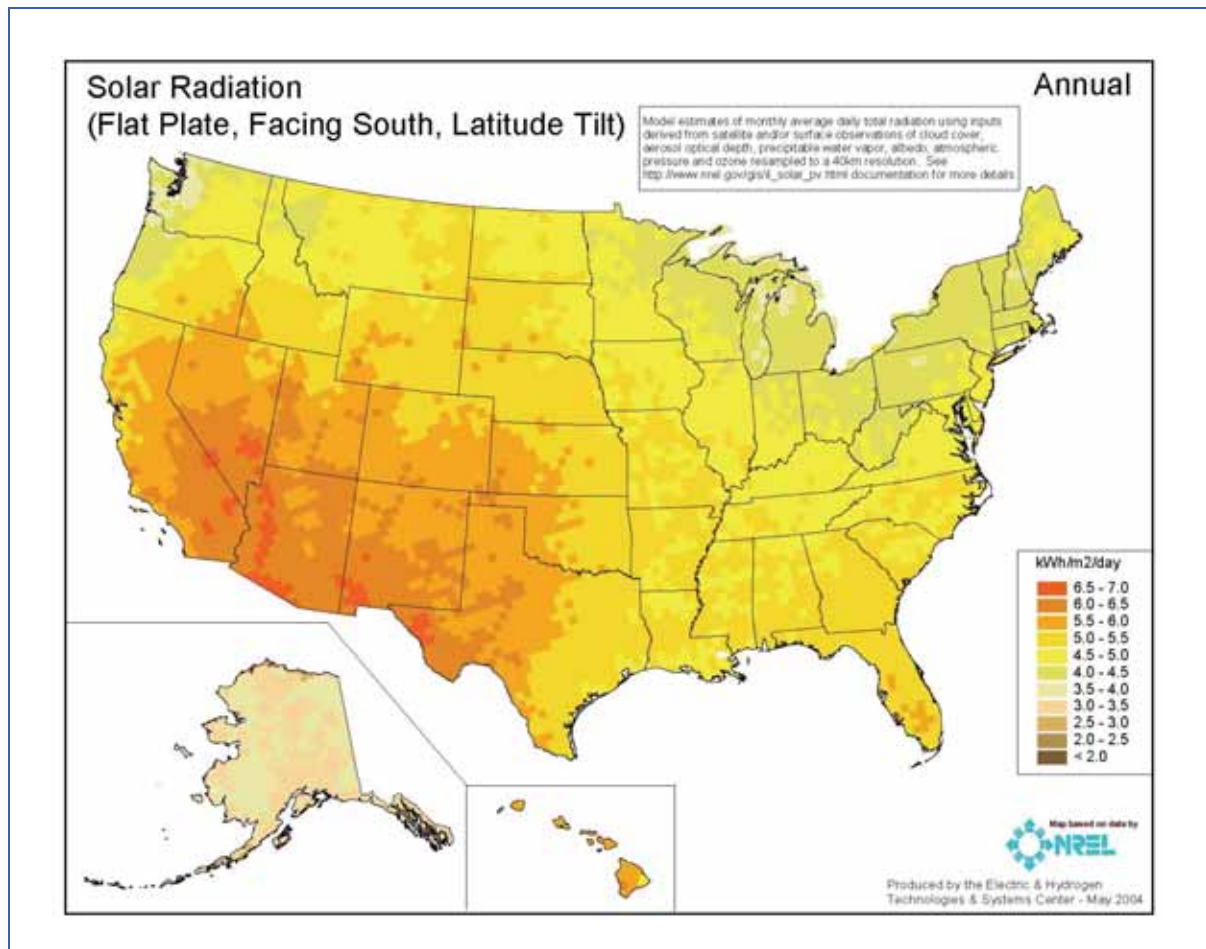


Figure 1 Average insolation in North America

1.3 Energy supplied by solar collector systems in relation to energy demand

Solar collector systems for DHW heating

Domestic hot water (DHW) heating is the most obvious application for solar collector systems. A relatively constant demand for hot water all year round is a good match for solar energy. Almost 100% of the energy demand for DHW heating during the summer can be covered by a solar system (Figure 2).

Nevertheless, a conventional backup system must still be able to cover the DHW demand independently of solar heating. Long periods of bad weather may occur during which the convenience of hot water still has to be assured.

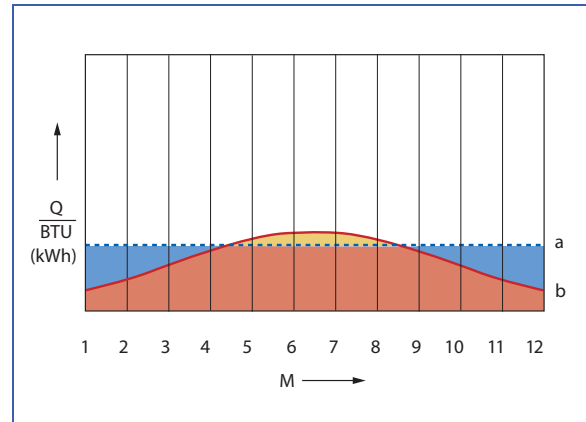


Figure 2 Energy provided by a solar collector system in relation to the annual energy demand for DHW heating.

Legend (Figure 2)

- a Energy demand
- b Energy provided by the solar system
- M Month
- Q Heating energy
- Solar energy surplus (available for a swimming pool, for example)
- Utilized solar energy (solar coverage)
- Energy demand that needs to be provided by the backup system (reheating)

2 Description of the solar system

The solar system consists of several components that were designed and selected to work together.

Solar system components:

- Collectors
- Line sets
- Pump station
- Storage tank
- Controller
- Backup heater

Solar collectors contain an absorber that heats up when exposed to sunlight. The absorber contains pipes that are filled with a fluid used to transport the solar heat to the tank where it can be stored for later use. When the fluid in the collectors is warmer than the bottom of the storage tank, the controller will turn on the pump to transport hot fluid from the collectors to the tank and replace it with cold fluid returning from the tank.

The collectors, the pump station, and the tank are connected with supply and return piping that is insulated to minimize losses. The system is equipped with over temperature and over pressure devices, that prevent unsafe operating conditions. These safety devices are mechanical and work even during a power outage.

As the system heats up or cools down, an expansion vessel (DEV) accounts for expansion and contraction of the fluid.

When the tank is satisfied and cannot accept any more heat, the system will stop and go into stagnation. The collector temperature will rise quickly causing the water in the fluid to turn to steam and force all fluids out of the collectors. The expansion tank takes in the added volume of the steam. Once the tank can accept heat again and the collectors have cooled to a safe temperature, the steam will liquefy and the system will be ready to collect more solar heat.

On days when more DHW is used than could be provided by the solar system, e.g. because guests are staying at the house or during a series of cloudy days with limited sunshine, a backup heater will provide added comfort. It is important that the backup heating system is capable of providing 100% of the demand to ensure comfort is never compromised.

3 Technical description of system components

3.1 Solar collectors

3.1.1 Bosch FKC-1 flat-plate collector

Selected features and characteristics

- Excellent price/performance ratio
- Consistently high yield through robust, highly selective black chromium coating
- SRCC OG-100 certified
- Rapid collector connection without the need for tools
- Easy handling because of light weight of 90 lbs (42 kg)
- Heat transfer fluid has long-term stability due to harp absorber with extremely good stagnation characteristics
- Energy-saving manufacturing with recyclable materials

Component design and functions

The housing of the Bosch FKC-1 solar collector consists of a lightweight, extremely strong fiber-glass frame profile. The back panel is made from 24 gauge (0.6 mm) galvanized sheet metal. The collector is covered with 1/8 inch (3.2 mm) thick single-pane tempered safety glass. The low-ferrous, structured castglass is coated, highly transparent (92% light transmission) and has extremely good load-bearing capability.

The 2-3/16 inch (55 mm) thick mineral wool provides extremely good thermal insulation and high efficiency. It is heat resistant and non-outgassing. The absorber consists of individual strips with a highly selective black chromium coating. It is ultrasonically welded to the harp fan in order to provide an extremely good heat transfer.

The Bosch FKC-1 has four pipe connections for making simple, rapid hydraulic connections. The solar pipes are fitted using spring clips that require no tools. They are designed for temperatures up to 370 °F (188 °C) and pressures of up to 87 psi (6 bar) in conjunction with the collector.

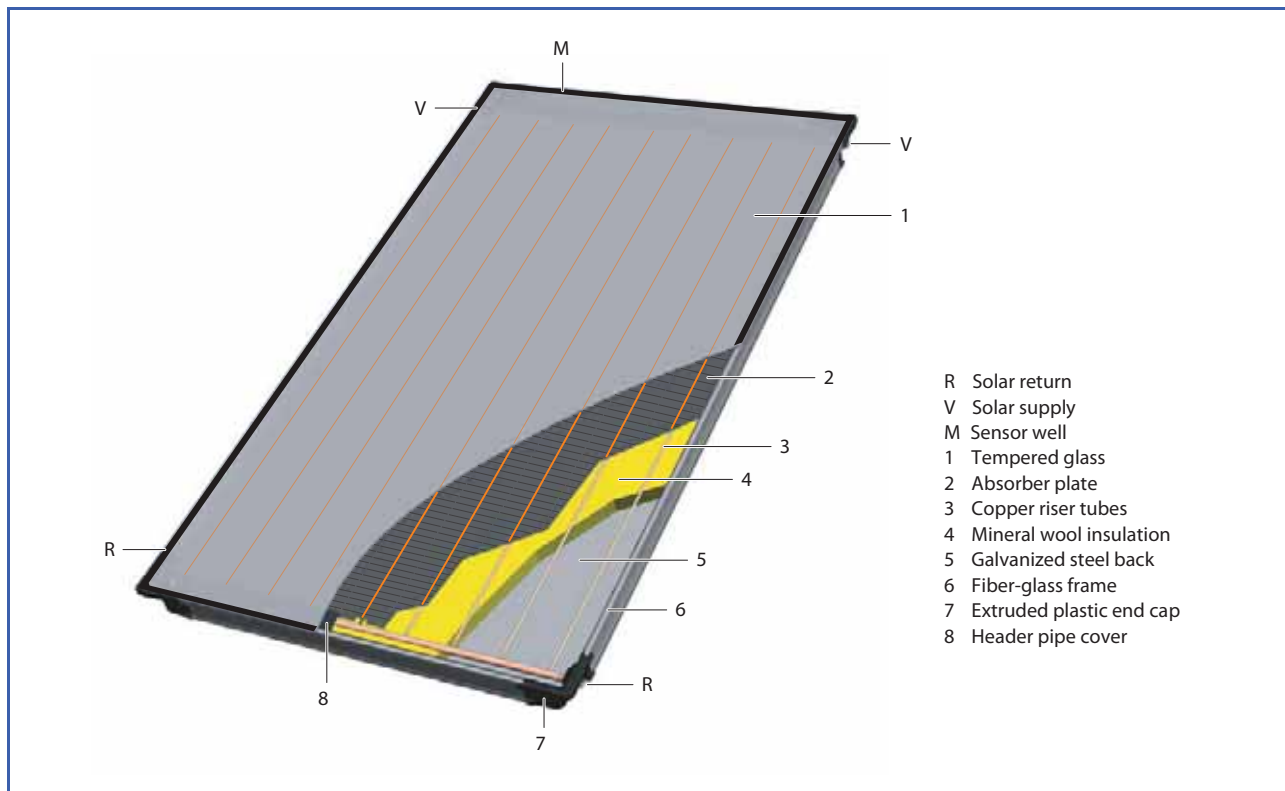


Figure 3 Design of Bosch FKC-1s flat plate collector

Dimensions and specification for Bosch FKC-1 flat-plate collectors

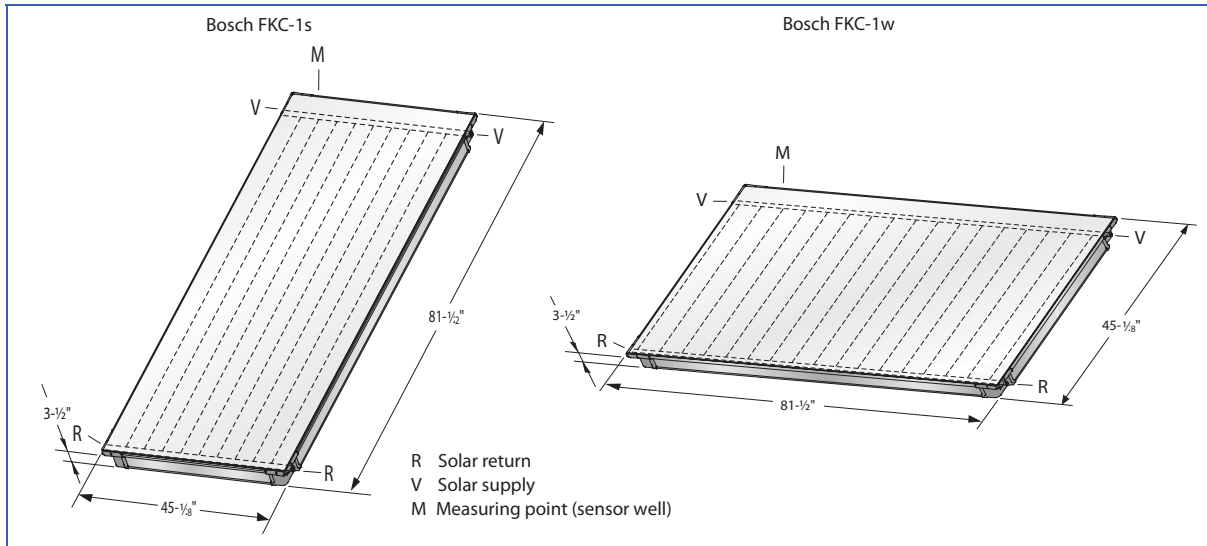


Figure 4 Dimensions of Bosch FKC-1-s (vertical) and Bosch FKC-1w (horizontal) flat-plate collectors; dimensions in inches

Bosch FKC-1 flat-plate collector		Bosch FKC-1s	
Type of installation		vertical	horizontal
Gross absorber surface area	ft ² (m ²)	25.96 (2.37)	
Aperture area (light entry area)	ft ² (m ²)	24.29 (2.26)	
Absorber contents	gal (l)	1/4 (0.86)	1/3 (1.26)
Weight	lbs (kg)	90 (41)	93 (42)
Absorptivity		95% ± 2%	
Emissivity		12% ± 2%	
Nominal flow rate	V gpm (l/h)	0.22 (50)	
Stagnation temperature	°F(°C)	370 (188)	
Max. operating pressure (test pressure)	psi (bar)	87 (6)	
Max. operating temperature	°F(°C)	248 (120)	

Figure 5 Specifications for Bosch FKC-1 flat-plate collector

3.1.2 Bosch FKB-1 flat-plate collector

Selected features and characteristics

- Affordable collector model with outstanding performance
- High output through, selective black lacquer coating
- SRCC OG-100 certified
- Rapid collector connection without the need for tools
- Easy handling because of light weight of 90 lbs (42 kg)
- Heat transfer fluid has long-term stability due to harp absorber with extremely good stagnation characteristics
- Energy-saving manufacturing with recyclable materials

Component design and functions

The housing of the Bosch FKB-1 solar collector consists of a lightweight, extremely strong fiber-glass frame profile. The back panel is made from 24 gauge (0.6 mm) galvanized sheet metal. The collector is covered with 1/8 inch (3.2 mm) thick single-pane tempered safety glass. The glass has a high light transmissivity (86%) and good load-bearing capability.

A 2-3/16 inch (55 mm) thick mineral wool provides extremely good thermal insulation and high efficiency. It is heat resistant and non-outgassing. The absorber consists of individual strips with a selective black lacquer coating. It is ultrasonically welded to the harp fan in order to provide an extremely good heat transfer.

The Bosch FKB-1 has four pipe connections for making simple, rapid hydraulic connections. The solar pipes are fitted using spring clips that require no tools. They are designed for temperatures up to 370 °F (188 °C) and pressures of up to 87 psi (6 bar) in conjunction with the collector.

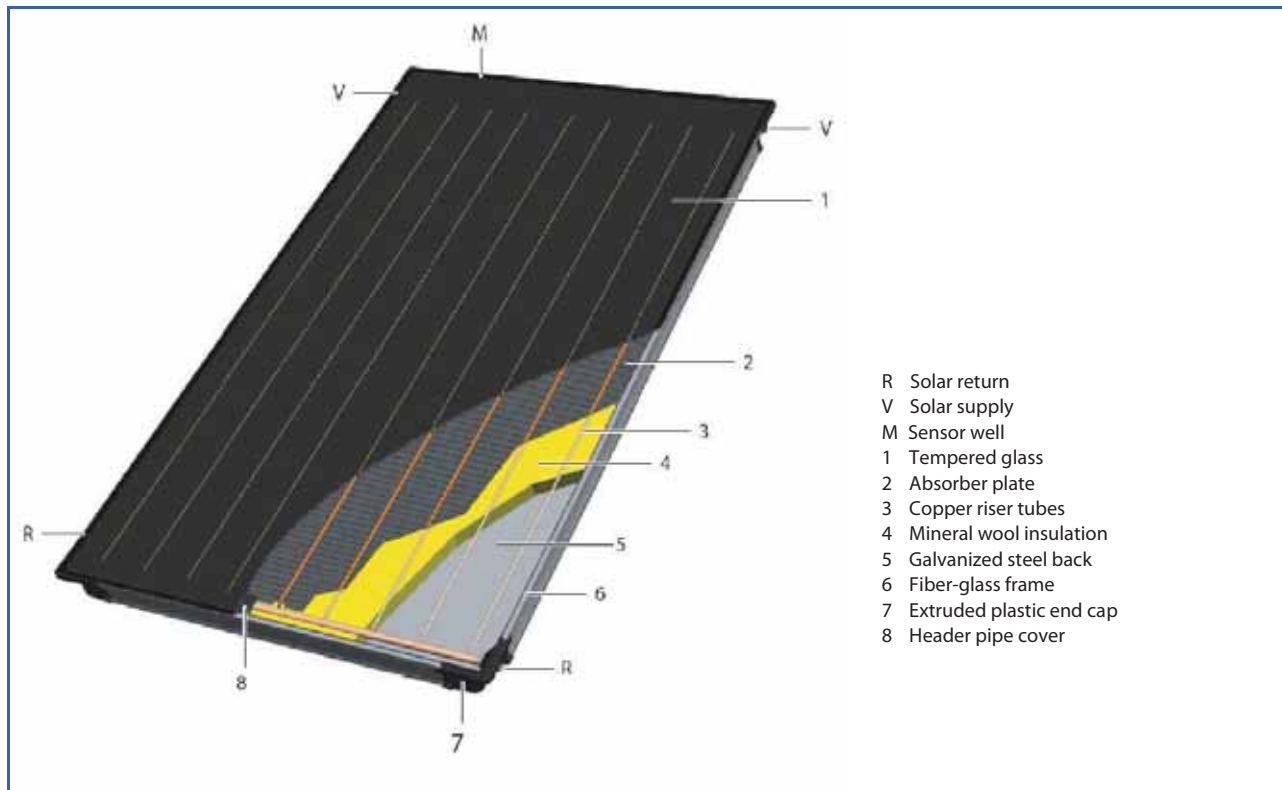


Figure 6 Design of Bosch FKB-1s flat plate collector

Dimensions and specification for Bosch FKB-1 flat-plate collectors

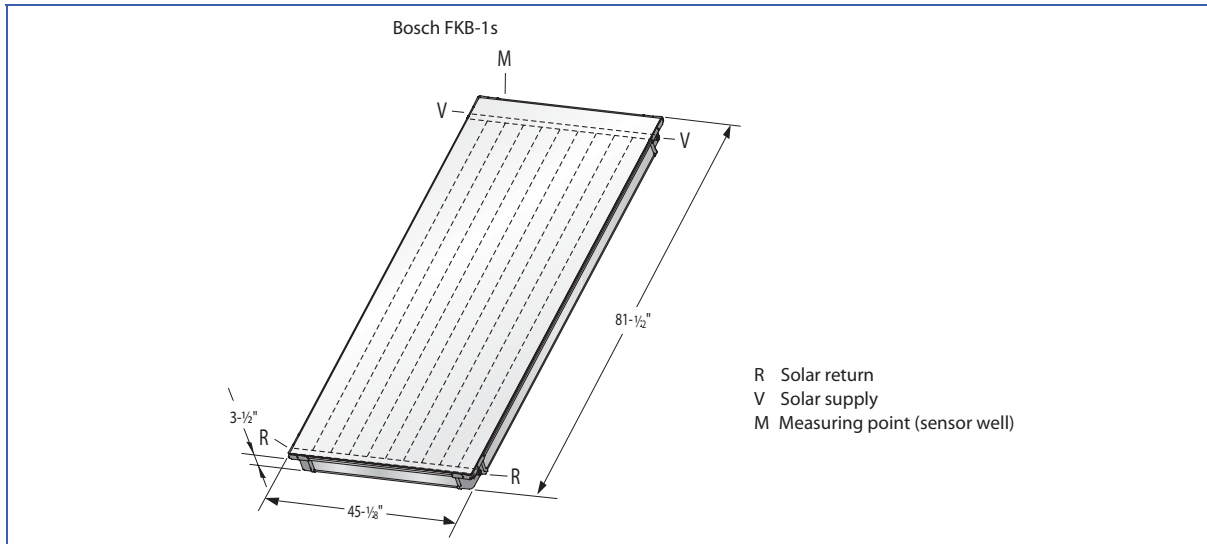


Figure 7 Dimensions of Bosch FKB-1-s (vertical) flat-plate collector; dimensions in inches

Bosch FKB-1 flat-plate collector		Bosch FKB-1s
Type of installation		vertical
Gross absorber surface area	ft ² (m ²)	25.96 (2.37)
Aperture area (light entry area)	ft ² (m ²)	24.29 (2.26)
Absorber contents	gal (l)	1/4 (0.86)
Weight	lbs (kg)	90 (41)
Absorptivity		86% ± 2%
Emissivity		30% ± 2%
Nominal flow rate	V gpm (l/h)	0.22 (50)
Stagnation temperature	°F(°C)	370 (188)
Max. operating pressure (test pressure)	psi (bar)	87 (6)
Max. operating temperature	°F(°C)	248 (120)

Figure 8 Specifications for Bosch FKB-1 flat-plate collectors

3.2 Solar storage tank

3.2.1 Indirect double wall coil storage tank

Available in 80 and 120 Gallon Models

- Temperature and pressure relief valve included
- Collector feed and return fittings located at front of tank for convenient installation
- Isolated tank design for better heat retention
- High efficiency heating element 4500W
- Rheemglas® tank lining resists corrosion and prolongs tank life
- Heat exchanger: copper tubing wrapped around and secured to the tank.
- Double wall, vented design for positive leak detection
- Cold water inlet brings cold water to tank bottom to prevent mixing with heated water
- Anode rod equalizes aggressive water action for prolonged tank life
- Cold water inlet, hot water outlet, relief valve and anode rod at top of tank for easy access and fast, economical installation
- Automatic temperature control
- Over temperature protector



Figure 9 Indirect double wall coil storage tank

Dimensions and specifications of indirect single coil solar tank

Description				Roughing in dimenstions			Energy information
Type	Gal. Cap.	Model number	Element wattage upper	Height (inches)	Diameter (inches)	Approx. ship wt. (lbs)	Approx. R-Factor
	80	SOL-RET80	4500 W*	58-¾	24-½	222	R-17.3
	120	SOL-RET120	4500 W*	62	28-½	380	R-17.3

Figure 10 Solaraide HE tank dimensions and specifications

* Heaters furnished with standard 240 volt AC, single phase non-simultaneous wiring and 4500 watt heating element.

Special features

- A special 1/2" NPT opening is provided for installation of a "probe type" thermostat.(Figure 11)
- Solaraide models meet all current state requirements for solar storage tanks.
- The tanks are Rheemglas lined and are designed to operate up to 150 PSI.

Note: To prevent corrosion, proper pH levels in transfer fluid must be maintained.

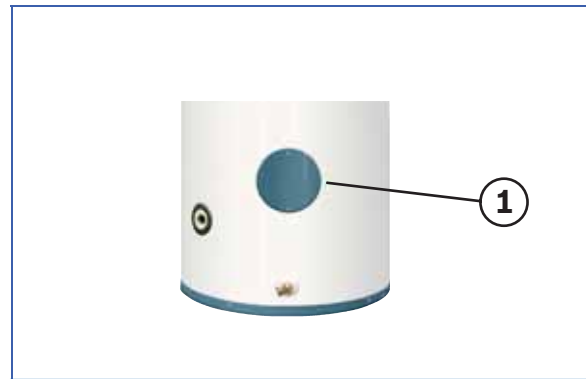


Figure 11 Opening for probe type thermostat

1) probe type thermostat access cover

Copper Coil Data (Type L Copper)

- Maximum pressure = 150 PSI
- Maximum temperature = 185° F
- Tube I.D. = 5/8"

SolaraideHE Tank Capacity	Coil Capacity (gallons)	Length of Tubing Around Tank (feet)	Approximate R-value of insulation
80 Gallons	2.2	120	R 17.3
120 Gallons	2.6	143	R 17.3

Figure 12 Copper coil data

Pressure Drop Through Coil (Feet of H ₂ O)		
Flow rate	Head Loss (Feet)	
	80 Gallon	120 Gallon
1 GPM	1.3	1.6
2 GPM	4.8	5.7
3 GPM	10.0	12.0

Figure 13 Pressure drop through coil

3.3 Solar controllers

Temperature differential control

In “Automatic” mode the solar controller monitors whether there is sufficient insolation to heat the solar storage tank. To do this, the controller compares the collector temperature using the collector sensor and the temperature in the lower area of the storage tank (tank sensor). If there is adequate insolation, i.e. the set temperature differential between the collector and the storage tank is exceeded, the solar circuit pump starts and the storage tank is heated. After a long period of

insolation and low DHW consumption, high temperatures occur in the storage tank. The solar circuit controller switches the solar circuit pump off when the maximum storage tank temperature has been reached. The maximum storage tank temperature can be set in the controller based on the individual requirements. The solar controller does not switch the pump off until the temperature differential has dropped below the minimum temperature.

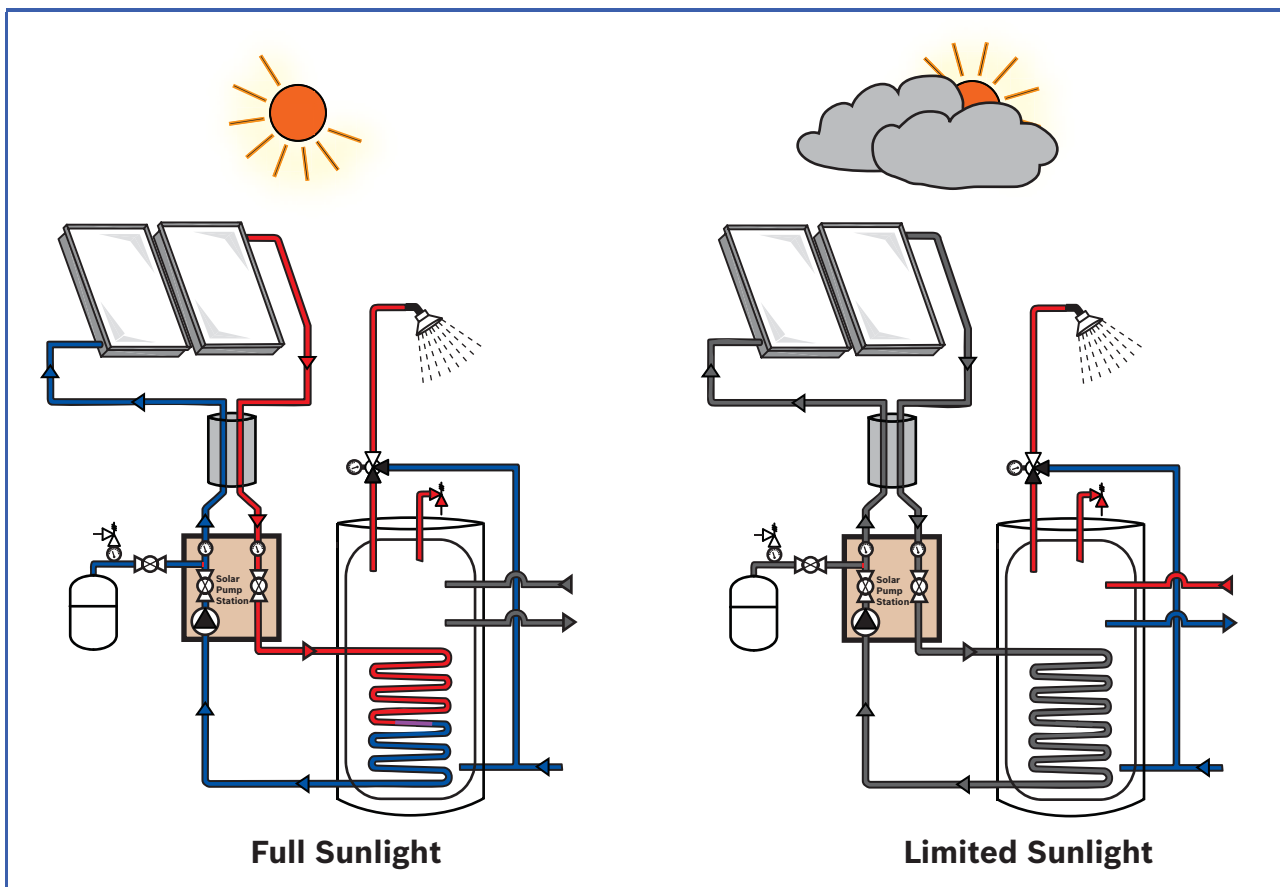


Figure 14 Function diagram of solar DHW heating with temperature differential control & flat plate collectors
 (Left) - with system running
 (Right) - conventional reheating if there is insufficient insolation

3.3.1 TR 0301 U Differential Temperature Controller

The standard delivery of the controller includes:

- One collector temperature sensor Pt1000 type
4.9 ft (1.5m) silicone cable with bushing
(Temperature limit 356 °F (+180 °C))
- One tank temperature sensor Pt1000 type
0.9 ft (1.0 m) twisted single conductor flat surface
sensors with compression cable lug (Temperature
limit 221 °F (+105 °C))

An optional 3rd tank temperature sensor (top) Pt1000 type 9.8 ft (3.0 m) twisted single conductor flat surface sensors with compression cable lug (Temperature limit 221 °F (+105 °C)) can be installed for informational purposes.

Automatic Storage Tank Loading

The TR0301 U controller constantly compares the temperatures between the collector (T1) and the lower area of the storage tank (T2) via temperature sensors. Once the sun heats the collector and there is a temperature difference of 16 °F (9 °C) between the collector and the storage tank, the pump is switched on and the pump symbol shown rotating on the display. The pump transports the heat transfer fluid from the storage tank to the collectors. There it is heated by the sun and transported back to the storage tank, where the heat is transferred to the domestic water. If the temperature difference between collector and storage tank falls below 8 °F (4.5 °C), the pump is switched off. The sun symbol is no longer shown on the display.

Automatic Stagnation

If the lower area of the storage tank (T2) reaches the set maximum storage tank temperature (factory default 140 °F (60 °C)), charging is stopped. A temperature of 6 °F (4 °C) below the maximum storage tank temperature must first be reached before charging can resume.

Automatic Pump Protection

During periods of high insolation, the temperature (T1) of the heat transfer fluid can exceed 266 °F (130°C). In order to protect the pump from overheating, the system will resume operation as soon as the temperature drops below 261 °F (127°C).

Vacation Function

The vacation function is used to cool down a completely heated storage tank via the collector. The storage tank can heat up too much if no DHW is drawn over an extended period of time (e.g. vacation). Discharging the solar system over night prevents the solar system idling in stagnation for extended periods.



Figure 15 Solar Controller TR0301U

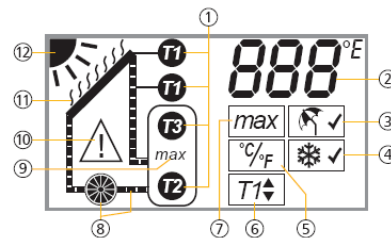


Figure 16 Display

Legend

- 1 Temperature sensor symbols
- 2 Temperature and faults code display
- 3 Vacation function
- 4 Anti-freeze function
- 5 Select temperature unit °C/°F
- 6 Evacuated tube collector function
- 7 Setting maximum storage tank temperature
- 8 Activated pump and fluid symbols indicate a system in operation
- 9 Indicates maximum storage tank temperature reached
- 10 Warning display if fault occurs
- 11 Indicates system stagnation
- 12 Shows sufficient heat for system operation

Anti-freeze Function

If the anti-freeze function is activated, the controller switches the pump on as soon as the collector temperature falls below +41 °F (+5 °C). The heat transfer fluid is then pumped through the collector and the system is prevented from freezing. If the collector reaches a temperature of +45 °F (7 °C), the pump is switched off.

3.3.2 TR 0603mc U Differential Temperature Controller

The TR 0603mc U is designed exclusively for the North America. The TR 0603mc U stores the system's operational data on a SD memory card, which can be used for data evaluation purposes.

The 40-programmed systems and numerous additional functions allow universal use of the controller. The large display panel shows the animated control circuits, which allows you to view the operating conditions of each system.

The TR 0603mc U has 6 inputs for recording temperature or pulse values, as well as an additional "Direct Sensor" input for combined temperature and flow rate measurement.

Pumps and switching valves are controlled by 3 outputs, some of which can be RPM controlled.



Figure 15 Solar Controller TR0301U

Product Features

- Animated LCD display with backlight
- Heating return increase
- Freely programmable thermostat function
- Timer and holiday (storage recool) functions
- Heat quantity (pulse generator / Direct Sensor/ calculation)
- Circulation function
- Back-up heating function measured in kwh/BTU
- Solid fuel boiler back-up heating
- Tube collector function
- Anti-freeze function
- Interval function
- Rapid storage tank loading
- Reduction of system stagnation phases
- Anti-legionella function
- Fault diagnosis and fault reporting output
- Bypass switching
- Data logging on SD card
- Seasonal systems (loading of pool / storage tank according to the time of the year)
- Multilingual menu navigation

Technical Data	
Operating voltage	120 VAC, 60 Hz [optional 240 VAC, 60 Hz]
Max. own consumption	≤ 4 W
Inputs	6 5 x temperature recording (Pt1000), 1 x temperature recording or pulse
Additional input	1 x "Direct Sensor" (temperature/flow rate)
Outputs	3 1 x relay switched output, max. 0.5 HP (120 V~) 2 x triac output for speed control, max. 0.17 HP (120 V~)
Additional output	1 x (fault reporting output)
Line cord	7', 18 AWG rated at 221 °F
Number of pre-defined hydraulic schemes	40
Interfaces	SD card, RS232, RS485 (TPC 1)
Data logging	SD card
Permitted ambient temperature	32 °F ... +113 °F (0 °C ... +45 °C)
Display	animated graphic LCD with backlighting
Protection class	IP 20/DIN 40050
Dimensions l x w x h	6.69 x 6.69 x 3.50 inch (170 x 170 x 89 mm)

3.4 Bosch KS pump stations

Features and characteristics

- The Bosch pump station assembly consists of all required components such as the solar circulator, the gravity brake, the safety pressure relief valve, the pressure gauge, ball valves in the flow and return with integrated thermometer, an adjustable flow limiter and thermal protection.

The Bosch KS pump station is designed for one solar storage tank. For two tanks two solar stations can be combined in one system. This arrangement provides two separate return connections with separate pumps and flow limiters. This enables the hydraulic balancing of two storage tanks with different pressure drop values.

Another application of two pump stations in one system is the implementation of a solar system with two collector arrays in different orientation (east/west control). Here too it is important to have two separate return connections with separate pumps and flow limiters. As previously described, hydraulic balancing of the two collector arrays with different pressure drop values is now feasible. Two safety assemblies (part of the standard delivery) and two diaphragm expansion vessels (DEV) are required for this arrangement.

Two collector arrays with different orientation are controlled using two independent solar controllers.

Configuration of the Bosch KS pump station

The solar stations for collector arrays with up to 5 collectors are already equipped with an air separator.

- The essential diaphragm expansion vessel (DEV) is not part of the standard delivery of the Bosch KS pump station. It must be sized for each individual case.

See chapter 5.5 Sizing of the Diaphragm Expansion vessel for details

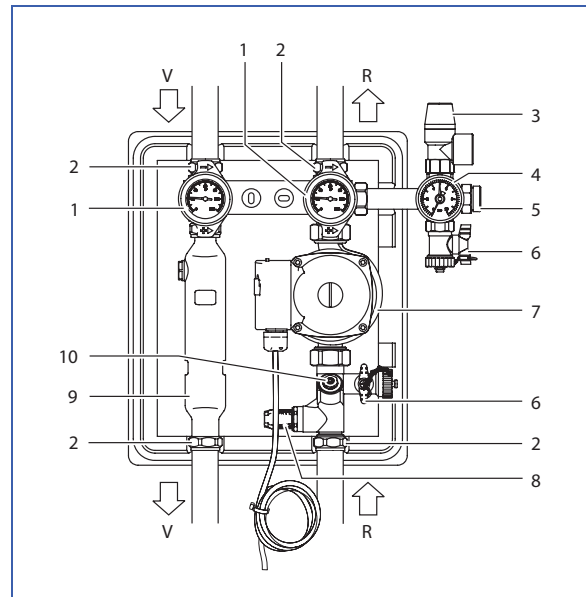


Figure 17 Layout of the Bosch KS0105 pump station

Legend

- V Supply from collector to storage tank
- R Return from storage tank to collector
- 1 Ball valve with thermometer and integrated gravity brake
Position 0° = gravity brake ready for operation, ball valve open
Position 45° = gravity brake manually open
Position 90° = ball valve closed
- 2 Compression ring fitting (all flow and return connections)
- 3 Safety relief valve
- 4 Pressure gauge
- 5 Connection for diaphragm expansion vessel
- 6 Fill & drain valve
- 7 Solar circuit pump
- 8 Flow volume indicator
- 9 Air separator
- 10 Regulating/shut-off valve

Dimensions and specification of Bosch KS pump station

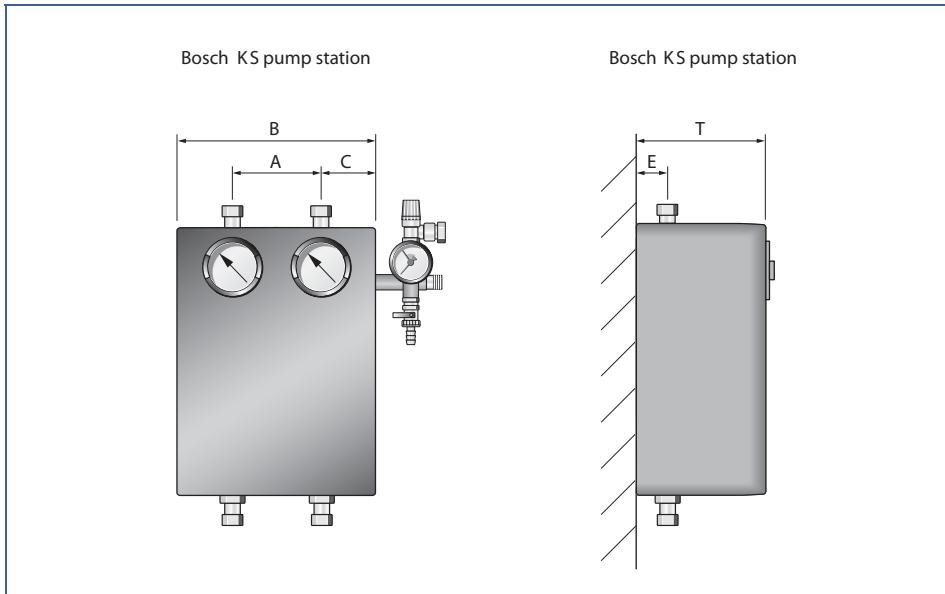


Figure 18 Dimensions of the KS pump stations

Pump station		KS0105	KS0110	KS0120	
Max. recommended # of collectors		5	10	20	
Number of storage tanks		1	1	1	
Casing dimensions	Height H	in (mm)	14" (355)	14" (355)	14" (355)
	Width W	in (mm)	11-1/2" (290)	11-1/2" (290)	11-1/2" (290)
	Depth D	in (mm)	9-1/4" (235)	9-1/4" (235)	9-1/4" (235)
Detailed dimensions	A	in (mm)	5-1/8" (130)	5-1/8" (130)	5-1/8" (130)
	C	in (mm)	3-1/8" (80)	3-1/8" (80)	3-1/8" (80)
	E	in (mm)	2" (50)	2" (50)	2" (50)
Copper pipe connection size (clamping ring fitting)	Supply/return	1/2" ID × 1	22 × 1	28 × 1	
Expansion vessel connection		3/4"	3/4"	3/4"	
Safety relief valve		psi (bar)	87 (6)	87 (6)	87 (6)
Circulation pump	Type		Grundfos Solar 15-58	Grundfos Solar 15-58	Grundfos UPS 25-99
	Finished length	in (mm)	5-1/8" (130)	5-1/8" (130)	5-1/8" (130)
Electrical power supply		V AC	120	120	120
Frequency		Hz	60	60	60
Max. power consumption		W	60	125	195
Max. current load		A	0.25	0.54	0.85
Throughput limiter adjusting range		gpm (l/min)	1/8 - 1-1/2 (0.5-6)	1/2 - 4-1/4 (2-16)	2 - 7 (8-26)
Weight		lbs (kg)	16 (7.1)	16 (7.1)	21 (9.3)
Flow range		gpm	0 - 17.5	0 - 17.5	0 - 34
Head range		feet	0 - 19	0 - 19	0 - 30
Motors			2 pole, single phase	2 pole, single phase	2 pole, single phase
Maximum fluid temperature		°F (°C)	230 (110)	230 (110)	230 (110)
Minimum fluid temperature		°F (°C)	36 (2)	36 (2)	36 (2)
Maximum working pressure		psi	145	145	145

Figure 19 Specification & dimensions of the KS pump station

3.5 Other system components

3.5.1 Twin-Tube piping system

Twin-Tube is a thermally insulated double tube for solar supply and return piping with UV protective jacket and integrated sensor lead.

Space for a bending radius of at least 5 inches (125 mm) for routing the Twin-Tube 1/2 inch must be available on site (Figure 20).

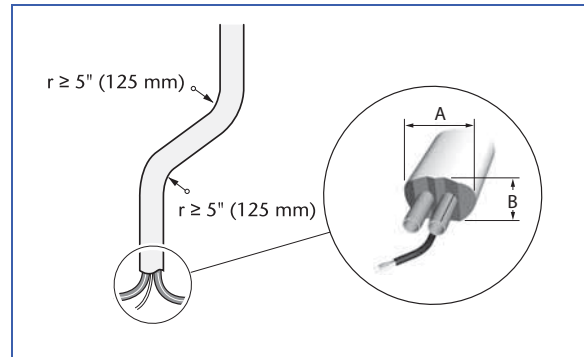


Figure 20 Bending radius for Twin-Tube 1/2 inch

Twin-Tube		1/2 INCH	
Dimensions	A	inch (mm)	3" (73)
	B	inch (mm)	2" (45)
Pipe dimensions	Diameter		2 × 1/2" ID inch
	Length	ft.	50
Insulating material			EPDM rubber
Insulation thickness		inch (mm)	2/3" (15)
Temperature resistant up to		° F (°C)	374 (190)
Protection film			PE, UV-resistant
Sensor lead			AWG18 (2 × 0.75 mm ²)

Figure 21 Twin-Tube specification

3.5.2 Lightning protection for the controller

The collector temperature sensor in the lead collector can be subject to overvoltage during a thunderstorm because of its exposed location on the roof. This overvoltage can damage the sensor and the controls.

The overvoltage protection is not a lightning rod. It is designed for situations where lightning strikes in the vicinity of the solar collectors. Safety diodes limit this overvoltage to a level that will not damage the controller.

The junction box must be located within 10 ft. (3.5 m) of the FSK collector temperature sensor (Figure 22).

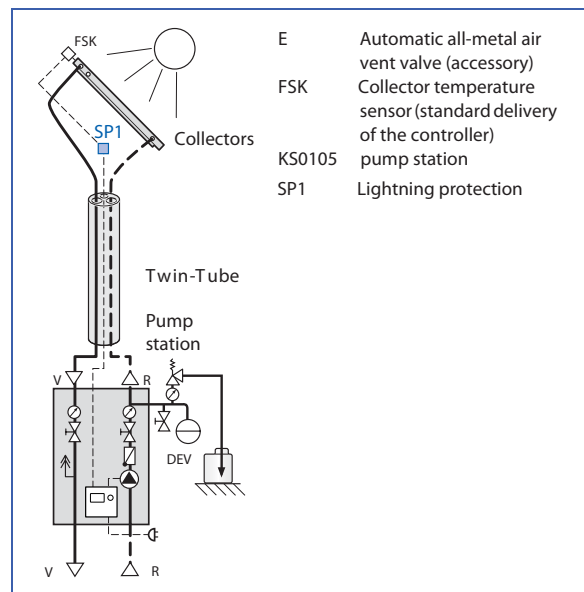


Figure 22 Overvoltage protection for controller example

3.5.3 Heat transfer fluid - Tyfocor L

Heat transfer fluid is used to transport solar heat from the collectors to the tank.

Bosch uses Tyfocor L, a premixed fluid of 45% propylene glycol and 55% water, and Tyfocor L “G”, a premixed fluid of 42% propylene glycol and 58% water. Both mixtures are clear, non-toxic, bio-degradable, and protect the system from freezing and corrosion.

Tyfocor L “G” uses FDA listed ingredients and must be used in systems that require OG-300 certification.

Both fluids provide frost protection down to -22°F (-30°C) and up to +338°F (+170°C).

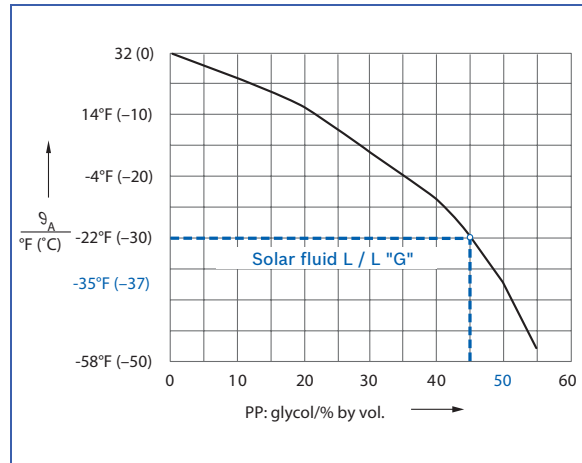


Figure 23 Level of frost protection of heat transfer fluid subject to the glycol-water mixture.

Legend (Figure 23)

s_A Outside temperature

Testing the heat transfer fluid

Heat transfer media based on mixtures of propylene glycol and water have a long service life if the system is sized well for the application and properly maintained.

The main influences on the service life of the solar fluid are repeated overheating and over pressure.

Aging is also accelerated by oxygen (air-borne systems) and impurities such as copper or iron shavings introduced during installation.

To check the heat transfer fluid on site, determine the pH value and the antifreeze value. Suitable pH indicator strips and a refractometer (frost protection) are included in the Bosch solar service kit.

Ready-mixed heat transfer fluid	pH value in the delivered condition	min. pH
Heat transfer fluid L 50/50	approx. 8	7

Figure 24 pH limits for checking ready-mixed heat transfer fluid

3.5.4 Thermostatically controlled domestic hot water mixer



WARNING: Hot water can scald. Solar systems can easily reach water temperatures that can scald. Take suitable measures to provide protection against scalding.

Anti-scald protection / tempering valve

If the maximum storage tank temperature is set higher than 122 °F (50 °C), take suitable measures to provide protection against scalding. The following options are available:

- Install a thermostatically controlled DHW mixing valve (tempering valve) downstream of the storage tank's DHW connection.

See Figure 25 for system integration of a thermostatically controlled DHW mixing valve (tempering) and a recirculation pump.

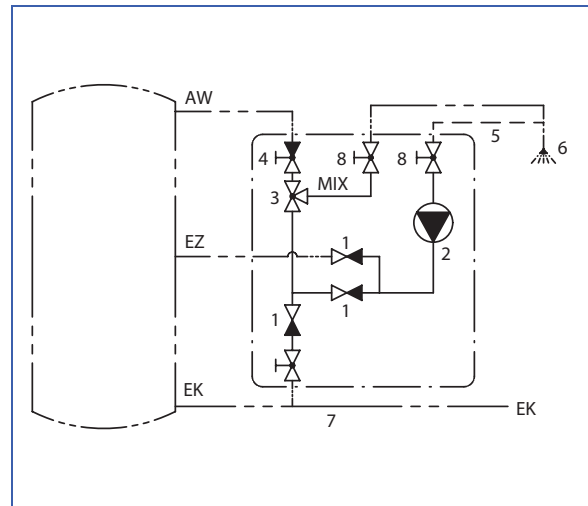


Figure 25 DHW tempering valve installation diagram with optional DHW recirculation line

Legend (Figure 25)

AW	DHW outlet
EK	Cold water inlet
EZ	DHW recirculation inlet (use is optional)
MIX	Mixed water
1	Check valve
2	DHW recirculation pump (optional)
3	Thermostatic mixing valve / tempering valve
4	Shut-off valve with check valve
5	DHW recirculation line
6	Faucet, shower, etc.
7	Cold water supply
8	Shut-off valve

4 Notes regarding solar systems

4.1 General information

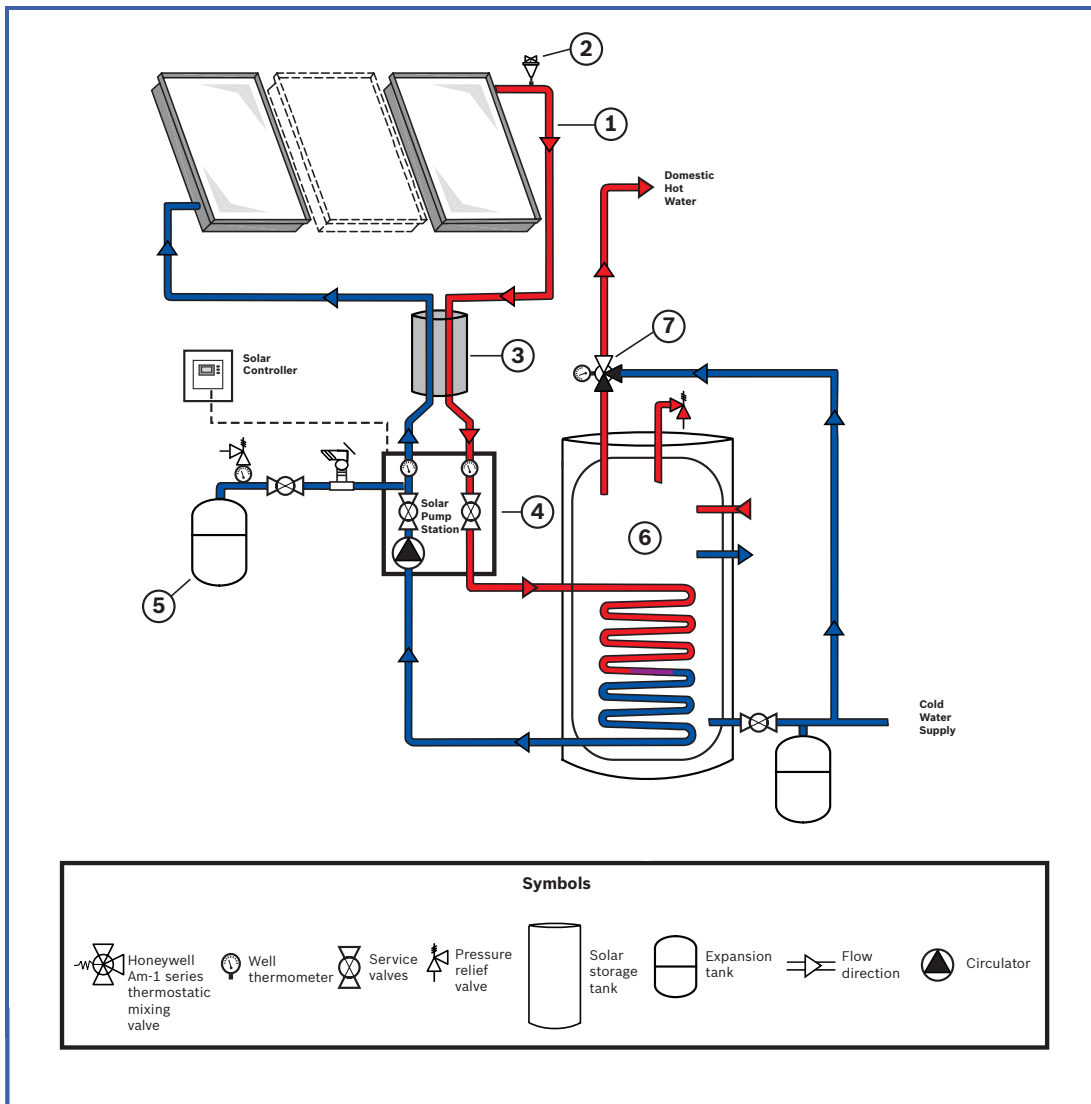


Figure 26 Sample diagram in connection with the general information regarding solar systems

Item	System components	General design
1	Collectors	The size of the collector arrays must be determined independently of the hydraulic system.
2	Pipework with incline to the air vent (Optional)	Installation of an air vent is not needed if a high head and high speed filling station is used for filling and charging the system. If an air vent is installed, position upright and at the highest point of the system, or at a secondary peak of the piping where air is expected to collect.
3	Connection lines Twin-Tube	For ease of installation, use of the double copper tube Twin-Tube 1/2" is recommended, complete with its heat and UV protection jacket and integrated FSK collector sensor cable. If Twin-Tube cannot be used install standard L-type copper piping and sensor cable on site (e. g. AWG18 (2 × 0.75 mm), and insulate appropriately.
4	Pump station	The Bosch KS0105 pump station contains all important hydraulic components for the solar circuit. The choice of pump station is subject to the number of storage tanks, the number/arrangement of collectors or connections, and the collector array pressure drop.

Figure 27 General information regarding solar systems.
(continued on the next page)

Item	System components	General design information
5	Diaphragm expansion vessel	Size the diaphragm expansion tank according to the system volume and the safety valve so that it can adequately compensate for the volume fluctuations in the system. With east/west systems an additional diaphragm expansion vessel is required for the 2nd collector array. A pre-cooling vessel is required if the DHW heating coverage is above 60% or in central heating systems.
6	DHW storage tank	Determine the size of the storage tank independently of the hydraulic system.
7	Hot water tempering valve	Reliable protection from excessively hot water temperatures (risk of scalding!) is provided by a thermostatically controlled hot water tempering valve (WWM). To prevent natural circulation, install the thermostatically controlled DHW mixing valve below the storage tank's DHW outlet. If this is not possible, provide a heat insulating loop or a check valve.
8	DHW water recirculation	DHW recirculation (not shown above) causes significant standby losses. Using a poorly designed DHW recirculation system can reduce the net solar yield considerably. Run recirculation pump on a timer only a few times per hour during peak demand times.

Figure 28 General information regarding solar systems

4.2 Regulations and guidelines for designing/engineering a solar system

Installation and commissioning must be carried out by a licensed and experienced contractor. Take appropriate personal safety measures when carrying out any installation work on the roof. Observe all relevant accident prevention regulations!

Apply all state-of-the-art technical standards to all work. Design the safety equipment in accordance with all applicable regulations. It is the installer's responsibility to comply with the building and installation codes in effect and all regulations that apply to the operation of a solar hot water system.

5 Sizing

5.1 Sizing principles

5.1.1 Solar DHW heating

Proper sizing of a solar thermal system for DHW heating is crucial for performance and comfort, fuel savings, and a long service life. Verify each case individually as to whether it is possible to upgrade an existing DHW system with a solar thermal system. The conventional heat source must be able to provide 100% of the hot water in a building independently of the solar system. A system putting too much emphasis on fuel savings may not meet the homeowner's approval if it does not provide DHW comfort during periods of bad weather.

Coverage of 50% to 60% over the course of a whole year is generally desirable for DHW heating systems for single family homes and two-family homes. Sizing for less than 50% is also realistic if the consumption data is unknown or unreliable. A coverage of less than 50% is generally appropriate in multifamily buildings.

5.1.2 Sizing with computer simulation

For larger solar thermal systems and systems for process water heating Bosch recommends using computer simulation for proper sizing:

- With six collectors or more, or
- If the system differs greatly from the calculation conditions in the sizing diagrams

Correct sizing essentially depends on the accuracy of the information on the actual DHW demand.

The following values are important:

- Daily DHW demand
- Daily profile, DHW demand
- Weekly profile, DHW demand
- Seasonal influence on the DHW demand (e. g. camp site)
- Set DHW temperature
- Existing DHW heating equipment (if an existing system is being extended)
- Recirculation losses
- Location
- Orientation
- Slope

T-Sol is an extremely practical simulation software for calculating solar systems. Simulation programs require consumption values as well as the size of the collector array and the storage tank. Consumption information should always be obtained, since values taken from literature are of little use.

The collector array and the solar storage tank must therefore be pre-sized for the computer simulation. The required output result is obtained in stages.

The T-Sol program a database of climate data such as temperatures, energy levels, efficiencies and coverage, as well as appliance data. This information can be displayed on screen in many different ways and can be printed out for further analysis and to prepare a quotation.

5.2 Sizing the collector array and solar heating storage tank

5.2.1 Systems for DHW heating in single family homes and two-family homes

Number of collectors

Empirical values from single family homes and two family homes can be used when a residential solar heating system for DHW heating is being sized. For larger systems and non-standard hot water demand, a T-Sol simulation (5.1.2 Sizing with computer simulation) is advisable. The following factors influence the optimum sizing of the collector array, the storage tank and the pumping station for solar collector systems for DHW heating:

- Location
- Roof slope (collector angle of inclination)
- Roof orientation (south-facing collector)
- DHW consumption profile

Take the draw-off temperature in accordance with the existing or intended sanitary equipment into consideration. The typical number of occupants and the average consumption per person per day are essential for a reasonably accurate estimation. Information about particular draw-off habits and comfort requirements are ideal.

Calculation principles

Figures 29 to 35 are based on a sample calculation with the following system parameters:

- Bosch FKC-1 flat-plate collectors
- 1-3 collectors: SOL-RET80 80 gal storage tank;
4+ collectors: SOL-RET120 120 gal storage tank;
- South-facing roof orientation
- Roof incline 45°
- Location Albany, NY
- Draw temperature 113 °F

Determining the number of collectors in accordance with figure 29 results in an annualized solar coverage of approx. 60%

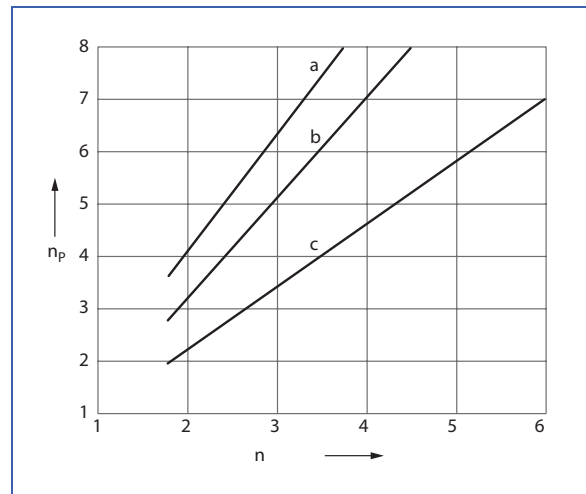


Figure 29 Diagram for an approximate determination of the number of Bosch FKC-1 collectors for DHW heating (observe calculation principles!)

Legend (Figure 29)

n Number of Collectors

n_p Number of occupants

DHW demand curves:

- a Low (< 10 gallons per person per day)
- b Average (13 gallons per person per day)
- c High (20 gallons per person per day)

Example

- Household with four occupants and a DHW demand of 50 gallons per day
- Solar system for DHW heating
- According to figure 29, curve b, two Bosch FKC-1 high-performance flat-plate collectors are required.

Influence of collector orientation and inclination on solar yield

Optimum angle of inclination for collectors

Use of solar heat for	Optimum angle of inclination of collectors
DHW	30° – 45°
Domestic hot water + swimming pool water	30° – 45°

Figure 30 Angle of inclination of collectors subject to the use of solar system

The optimum angle of inclination depends on the use of the solar system. For constant year-round use, the collector angle should reflect the latitude of the location. For better results during the winter months, use angles greater than the latitude. Angles shallower than the latitude are typically not recommended as they reduce performance in the winter and offer little performance increase during the summer months. In snowy climates shallow collector angles may lead to snow accumulation and further reduce performance.

Collector orientation

Orientation of the solar collectors with the points on the compass and the pitch have an influence on the thermal energy that can be harvested by a collector array. For maximum solar yield align the collectors at an angle of inclination close to the latitude of the site, and within 10° East or West of due South.

If the collector array is mounted on a steep roof or a wall, the orientation of the collector array is identical to that of the roof or wall. If the collector array orientation deviates to the east or west, the rays of the sun will no longer strike the absorber area in the most effective way. This will reduce the performance of the collector array.

According to Figure 31 there is a correction factor for every collector array deviation from due South, and subject to the degree of its pitch. The collector area that was determined under ideal conditions must be multiplied by this factor to achieve the same energy yield as is achieved with direct southern orientation.

Angle of Inclination	Correction factors for collector orientation deviation from south												
	Deviation to the west by						South	Deviation to the east by					
	90°	75°	60°	45°	30°	15°	0°	-15°	-30°	-45°	-60°	-75°	-90°
Lat + 20°	1.26	1.19	1.13	1.09	1.06	1.05	1.05	1.06	1.09	1.13	1.19	1.26	1.34
Lat + 15°	1.24	1.17	1.12	1.08	1.05	1.03	1.03	1.05	1.07	1.12	1.17	1.24	1.32
Lat + 10°	1.23	1.16	1.10	1.06	1.03	1.02	1.01	1.04	1.06	1.10	1.16	1.22	1.30
Lat + 5°	1.21	1.15	1.09	1.05	1.02	1.01	1.00	1.02	1.04	1.08	1.14	1.20	1.28
Latitude	1.20	1.14	1.09	1.05	1.02	1.01	1.00	1.02	1.04	1.08	1.13	1.19	1.26
Lat - 5°	1.20	1.14	1.09	1.05	1.02	1.01	1.01	1.02	1.04	1.08	1.12	1.18	1.25
Lat - 10°	1.19	1.14	1.09	1.06	1.03	1.02	1.01	1.03	1.05	1.08	1.13	1.18	1.24
Lat - 15°	1.19	1.14	1.10	1.07	1.04	1.03	1.03	1.04	1.06	1.09	1.13	1.17	1.22

Correction ranges: 1.00–1.05 1.06–1.10 1.11–1.15 1.16–1.20 1.21–1.25 > 1.25

Figure 31 Correction factors with south deviation of Bosch solar collectors for different angles of inclination

Example

- Parameters
 - Household with four occupants with DHW demand of 50 gallons per day
 - Location: Albany, NY (approx. 40° Latitude)
 - Angle of inclination 25° with rooftop installation of Bosch FKC-1 solar collectors
 - Deviation to the west by 60°
- Measure
 - 1.8 Bosch FKC-1 collectors
 - 40° Latitude - 15° = 25° roof pitch
 - Correction factor 1.10
 - The calculation results in: $1.8 \times 1.10 = 2.0$

To achieve the same energy yield as with direct southerly orientation, allow for 2 Bosch FKC-1 solar collectors.

Storage tank selection

A suitable ratio between collector output (size of collector array) and storage tank capacity (storage tank volume) is needed to make a solar heating system operate efficiently. The size of the collector array is limited by the storage tank capacity (Figure 32).

Rule of thumb

A storage tank volume of twice the daily demand has proven to be adequate. Figure 32 shows standard values for selecting the DHW storage tank subject to the DHW demand per day depending on the number of occupants. A storage tank temperature of 140 °F (60°C) and a draw-off temperature 113 °F (45 °C) have been assumed. In a multi-storage tank system the stored volume of DHW should be able to cover twice the daily demand with a draw-off level of 85%.

DHW storage tank	Recommended daily DHW demand in gallons with storage tank temperature of 140 °F (60 °C) and draw-off temperature of 113 °F (45 °C)	Recommended number of occupants with a DHW demand per person per day of			Capacity gallons	Rec. no. ¹⁾ Collectors FKC-1 or FKB-1
		10 gallons Low	13 gallons Average	20 gallons High		
SOL-RET80	up to 53/66	approx. 5-6	approx. 4-5	approx. 3	80	2-3
SOL-RET120	up to 66/80	approx. 6-8	approx. 5-6	approx. 3-4	120	3-4

Figure 32 Standard values for selecting DHW storage tank

1) Determining the number of collectors

Daily heating/disinfection control

Follow local codes and regulation for disinfection and prevention of Legionnaires’ disease outbreak.

Collector area sizing

Apply a daily consumption of approx. 1.8 - 2.0 gallons of DHW at 140 °F (60 °C) per ft² of collector area for sizing the collector area in properties with a uniform consumption profile, such as in multifamily buildings.

By way of simplification, the following formula can be used taking the specified marginal conditions into consideration:

Marginal conditions for formula

- Re-circulation cost: 340 BTU/hr per unit (100W/unit)
Old building: 480 BTU/hr per unit (140W/unit)
- Pre-heat storage tank temperature max. 167 °F (75 °C), water transfer enabled
- 26 gal per unit at 140 °F (100 l/unit at 60 °C)

$$n_{\text{collector}} = 0.7 \cdot n_{\text{WE}}$$

Figure 33 Formula for the required number of Bosch FKC-1 solar collectors in relation to the number of residential units (observe marginal conditions!)

Calculating sizes

- $n_{\text{collector}}$ Number of Bosch FKC-1 solar collectors
- n_{WE} Number of residential units

5.3 Space requirements for solar collectors

5.3.1 Rooftop installation

On pitched roofs Bosch solar collectors can be installed with a pitch of 25° to 65°. Installation on corrugated sheet and standing seam metal roofs is only permissible on roof pitches between 5° and 65°.

Besides the area above the roof, the space required underneath the roof must also be taken into consideration.

Dimensions A and B represent the area requirement for the selected number and layout of collectors.

Dimension C represents the minimum distance from the ridge.

Dimension D represents the roof overhang, including the gable end thickness.

Allow 20 inches to the right and/or left of the collector array for the connection lines (underneath the roof!).

Allow 12 inches beneath the collector array (underneath the roof!) for routing the return connection line.

Route the return line with a rise to the automatic air vent valve (if installed).

Allow 16 inches above the collector array (beneath the roof!) for routing the flow header (rising) and the automatic air vent (if installed).

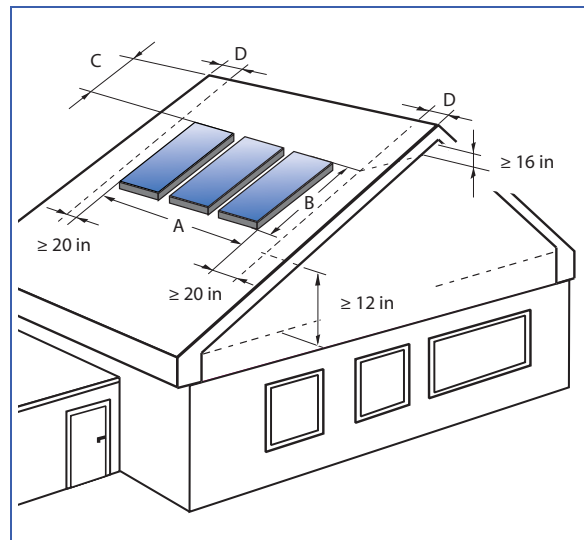


Figure 34 Space requirements on the rooftop

Area required for solar collector rooftop installation

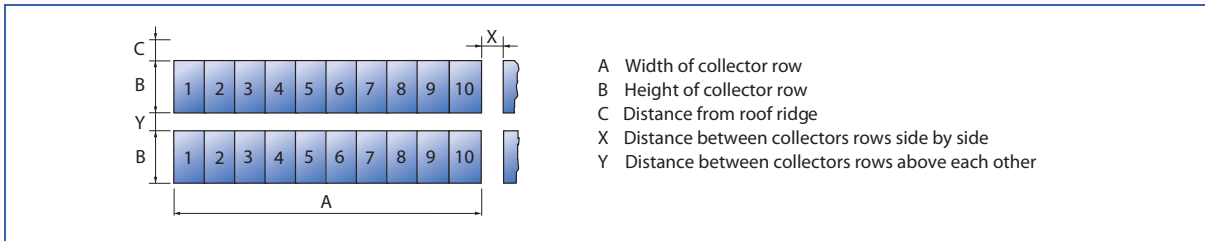


Figure 35 Area required for collector arrays for rooftop installation

Dimensions			Collector array dimensions for Bosch flat-plate collectors	
			Bosch FKC-1 and FKB-1 at rooftop installation	
			FKC-1 and FKB-1 vertical	FKC-1 horizontal
A	for 1 collector	in	45-1/4"	81-1/2"
	for 2 collectors	in	91-3/8"	164-3/16"
	for 3 collectors	in	137-7/16"	246-1/2"
	for 4 collectors	in	183-1/2"	329-1/8"
	for 5 collectors	in	229-1/2"	411-3/8"
B		in	81-1/2"	45-1/4"
C		in	12" or 2 rows of tiles	12" or 2 rows of tiles
X		in	8"	8"
Y			subject to roof construction (batten spacing)	subject to roof construction (batten spacing)

Figure 36 Collector array dimensions with Bosch flat-plate collectors for rooftop installation

5.3.2 Flat roof installation

Flat roof installation is possible with vertical and horizontal collectors. The area required for the collectors corresponds to the installation area for the flat roof supports used plus a space for pipework routing. This space should be at least 20 inches (50 cm) to the left and right of the array. Maintain a minimum distance of 30 inches (100 cm) from the roof edge. In locations with snowfall, consider that snow will slide off the collectors and may accumulate at their base.

In areas with large amounts of snowfall consider measures for snow removal to minimize service interruptions.

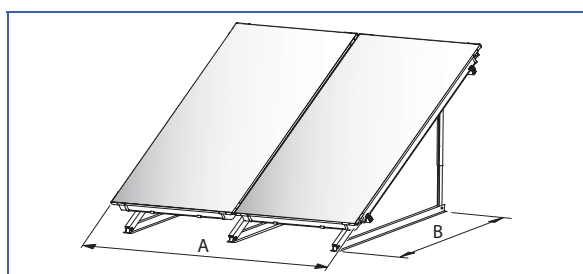


Figure 37 Flat roof stand installation dimensions on the example of Bosch FKC-1 vertical flat-plate collectors (dimension A - Figure 36 and dimension B - Figure 37)

Angle of inclination	Collector row dimensions	
	FKC-1 and FKB-1 vertical	FKC-1 horizontal
	B in	B in
25°	72-7/16"	41-3/4"
30°	68-7/8"	40-3/16"
35°	66-1/8"	37-3/16"
40°	62-3/16"	35-13/16"
45°	58-1/4"	33-7/16"
50°	58-1/4"	33-7/16"
55°	58-1/4"	33-7/16"
60°	58-1/4"	33-7/16"

Figure 39 Collector row dimensions when using flat roof supports.

Number of collectors	Collector row dimensions	
	FKC-1 and FKB-1 vertical	FKC-1 horizontal
	A in	A in
2	92-1/8"	164-1/2"
3	138-3/16"	247-1/4"
4	184-1/4"	330"
5	230-5/16"	412-5/8"

Figure 38 Collector row dimensions when using flat roof supports

5.3.3 Space requirements for wall mounting

Bosch flat-plate collectors

Only Bosch FKC-1 horizontal flat-plate collectors are suitable for wall mounting, and only for an installation height of up to 65 ft above ground. The wall must have adequate loadbearing capacity!

The space requirement on the wall for the collector rows depends on the number of collectors. In addition to the width of the collector array, allow at least 20 inches to the left and right (dimension A, Figure 40) for routing the pipework. The space between the collector row and the edge of the wall must be at least 3ft. (1.0m).

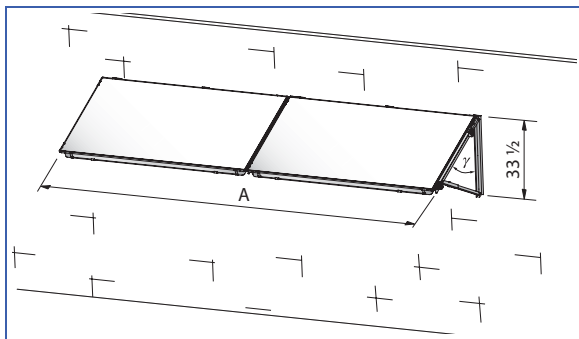


Figure 40 Installation dimensions of wall mounting kits for Bosch FKC-1 horizontal flat-plate collectors; dimensions in inches (dimension A - Figure 42)

Number of collectors	Collector row dimensions for Bosch FKC-1
	horizontal
	A
	in
2	164-1/8"
3	246-1/2"
4	329-1/8"
5	411-3/8"

Figure 41 Collector row dimensions when using wall mounting supports

Minimum row spacing

The wall mounting kit is particularly suitable for buildings with non-ideal roof orientation, or where shading of windows and doors is desired. This allows taking advantage of the sun while creating an architectural feature.

Collectors can be mounted to provide ideal shade for windows and keep rooms nice and cool. In winter, when the sun's path is lower, solar gain can provide an additional source of energy.

Several rows of collectors arranged above of each other must be kept at least 145 inches apart to prevent the collectors from casting shadows on each other (Figure 41).

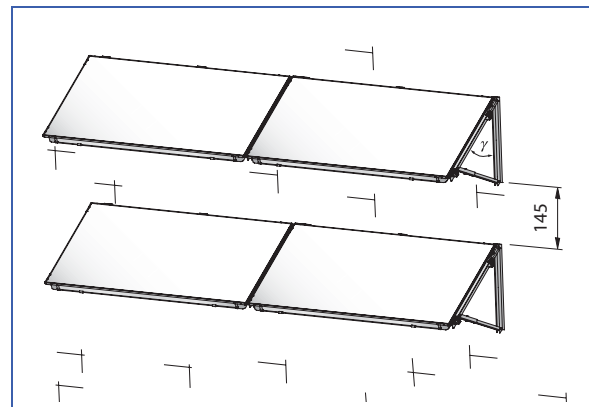


Figure 42 Shade-free spacing for several rows of wall installation kits for horizontal flat-plate collectors arranged above each other. Dimensions in inches

Snow and ice accumulating on the collectors may give way and slide off suddenly. Take provisions that the installation does not pose a risk to property and cause personal injury from falling snow and ice.

5.4 Hydraulic system engineering

5.4.1 Hydraulic circuit

Collector array

A collector array must consist of the same type of collectors and have the same orientation (all vertical or all horizontal). This is necessary, since the flow distribution would otherwise not be uniform. A maximum of ten Bosch FKC-1 or FKB-1 flat-plate collectors may be installed in a row and hydraulically connected in parallel if the supply and return connections are on alternate sides. In small systems it is preferable to connect collectors in series. Connecting the collectors in parallel is better in larger systems. This allows a more uniform volume flow distribution of the entire array.

Connection in series		Connection in parallel	
Row(s)	Max. number of collectors per row	Row(s)	Max. number of collectors per row
1	10	1	With supply and return on opposite sides max. 10 collectors per row
2	5	2	
3	3	3	
4	Never connect more than three rows in series!	4	
		...	
		n	

Figure 43 Collector array layout options

Connection in series

The hydraulic connection of collector rows in series is accomplished quickly because of the simple connection design. Connection in series is the preferred way to achieve a uniform volume flow distribution.

If there are several arrays (rows) in a system, the number of collectors per row may not differ by more than one.

The maximum number of flat-plate collectors connected in series is limited to 10 collectors and 3 rows (Figure 43).

The hydraulic connection is shown in the following diagram in the example of a rooftop installation. Additional automatic air vent valves may be required if such valves cannot be installed at the highest point (i.e. flat roof installation).

Collector array with dormer

The following hydraulic scheme represents one option for solving the challenge posed by dormers. It is important that the maximum number of collectors in one row in series is not exceeded.

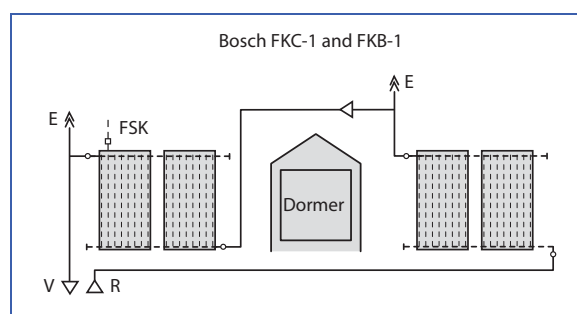


Figure 44 Hydraulic connection of collector arrays that are interrupted by a dormer

5.4.2 Flow rate in the collector array

The nominal flow rate for engineering small and medium-sized systems is 0.22 gpm (50l/h) per collector, resulting in a total system flow rate per formula (Figure 45).

A flow rate 10% to 15% lower (at full pump speed) does not usually lead to significant yield reductions. However, avoid higher flow rates to minimize the amount of power required by the solar circuit pump.

$$\dot{V}_A = \dot{V}_{k,Nom} \cdot n_k = 0.22gpm \cdot n_k$$

Figure 45 Formula for total system flow rate

Calculating sizes

- \dot{V}_A Total system flow rate in gpm
- $\dot{V}_{k,Nom}$ Nominal flow rate of collector in gpm
- n_k Number of collectors

5.4.3 Pressure drop calculation in collector array

Collector row pressure drop

The pressure drop of a collector row increases with the number of collectors. The pressure drop for a row including accessories, subject to the number of collectors per row, can be found in Figure 46.

The pressure drop values for the Bosch FKC-1 and FKB-1 collectors for a solar fluid mixture consisting of 50% glycol and 50% water at a mean temperature of 122°F (50°C) are specified in Figure 46.

Number of collectors	Pressure drop for a row consisting of n collectors					
	Bosch FKC-1 and FKB-1 vertical			Bosch FKC-1 horizontal		
	at a flow rate per collector (nominal flow rate 0.22 gpm)					
n	0.22 gpm in H ₂ O	0.44 gpm ¹⁾ in H ₂ O	0.66 gpm ²⁾ in H ₂ O	0.22 gpm in H ₂ O	0.44 gpm in H ₂ O	0.66 gpm in H ₂ O
1	0.44	1.89	4.09	0.16	0.68	1.72
2	0.60	2.6	5.23	0.76	2.77	5.78
3	0.84	5.42	10.56	2.25	7.27	14
4	2.6	8.87	–	3.73	11.92	–
5	4.45	13.85	–	5.94	18.79	–
6	6.1	–	–	8.55	–	–
7	8.43	–	–	11.6	–	–
8	11.2	–	–	15	–	–
9	14.4	–	–	19	–	–
10	18	–	–	23.52	–	–

Figure 46 Pressure drop values for collector rows with Bosch FKC-1 including AAV and connection kit; pressure drop values apply to solar fluid L at an average temperature of 122°F (50°C)

- 1) Flow rate per collector, connected in two row
- 2) Flow rate per collector, connected in three rows - Non-permitted

Rows of collectors connected in series

The pressure drop of the array results from the sum of all pipework plus each row of collectors. The pressure drop of rows of collectors connected in series is cumulative.

$$\Delta p_{\text{Array}} = \Delta p_{\text{Row}} \cdot n_{\text{Row}}$$

Figure 47 Formula for pressure drop of a collector array with rows of collectors in series

As far as Figure 48 is concerned, take into consideration that the actual flow rate is calculated from the individual collectors connected in series, the number of rows, and the nominal collector flow rate (0.22 gpm):

$$V_k = V_{k, \text{Nom}} \cdot n_{\text{Row}} = 0.22 \text{ gpm} \cdot n_{\text{Row}}$$

Figure 48 Formula for flow rate through a collector with rows of collectors connected in series

Calculation parameters (Figure 47 and 48)

Δp_{Array}	Pressure drop for collector array in in. W.C.
Δp_{Row}	Pressure drop for one collector row in in. W.C.
n_{Row}	Number of collector rows
V_k	Flow rate through the individual collectors in gpm
$V_{k, \text{Nom}}$	Nominal flow rate of collector in gpm

Example

- Parameters
 - Connection in series of 2 collector rows, each with 5 Bosch FKC-1 or FKB-1 solar collectors
- Wanted
 - Pressure drop of collector system
- Calculation
 - Flow rate through one collector:

$$V_k = V_{k, \text{Nom}} \cdot n$$

$$V_k = 0.22 \text{ gpm} \cdot n_{\text{Row}} = 0.22 \text{ gpm} \cdot 2 = 0.44 \text{ gpm}$$
 - Read from Figure 50:
 - 13.85 in. H₂O per collector row
 - Pressure drop of array:

$$\Delta p_{\text{Array}} = \Delta p_{\text{Row}} \cdot n_{\text{Row}} = 13.85 \text{ in. H}_2\text{O} \cdot 2 = 27.2 \text{ in. H}_2\text{O}$$

The pressure drop of the collector array is 27.2 in. H₂O.

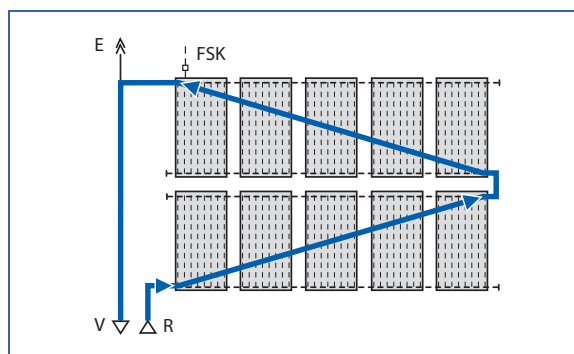


Figure 49 Connection in series of two collector rows

Collector rows connected in parallel

The pressure drop for the array results from the total of the pipework pressure drop values up to a collector row and the pressure drop of an individual collector row.

$$\Delta p_{\text{Array}} = \Delta p_{\text{Row}}$$

Figure 50 Formula for the pressure drop of a collector array with rows of collectors connected in parallel

Unlike the situation when connecting in series, the actual flow rate via the individual collectors corresponds to the nominal collector flow rate of 0.22 gpm (50 l/h).

$$V_k = V_{k, \text{Nom}}$$

Figure 51 Formula for the flow rate through a collector with rows of collectors connected in parallel

Calculation parameters (Figure 50 and 51)

Δp_{Array} Pressure drop for collector array in. W.C.

Δp_{Row} Pressure drop for one collector row in. W.C.

V_k Flow rate through the individual collectors in gpm

$V_{k, \text{Nom}}$ Nominal flow rate of collector in gpm

Example

- Parameters
 - Connection in parallel of 2 collector rows, each with 5 solar collectors
- Wanted
 - Pressure drop of overall collector array
- Calculation
 - Flow rate through one collector:

$$V_k = V_{k, \text{Nom}} \cdot n = 0.22 \text{ gpm}$$
 - Read from Figure 50:

$$4.45 \text{ in. H}_2\text{O per collector row}$$
 - Pressure drop of array:

$$\Delta p_{\text{Array}} = \Delta p_{\text{Row}} = 4.45 \text{ in H}_2\text{O}$$

The pressure drop of the collector array is 4.45 in. H₂O

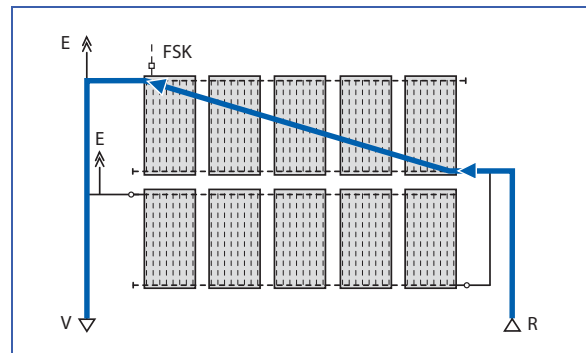


Figure 52 Two collector rows connected in parallel using reverse-return piping

5.4.4 Pressure drop of pipework in the solar circuit

Calculating the pipework

The flow velocity in the pipework should be in excess of 1.3 ft/sec to allow air remaining in the heat transfer medium to be transported to the next air separator. Flow noise can occur from velocities of 3 ft/sec and higher. Take

individual resistance values (caused by bends, for example) into consideration in the pressure drop calculation by adding 30% to 50% to the pressure drop of the straight pipework.

Number of collectors	Flow rate gpm	Flow velocity v and pressure drop R in copper pipes with pipe dimensions of	
		1/2 inch	
		v ft/s	R in H ₂ O/ft
2	0.44	0.69	0.11
3	0.66	1.00	0.17
4	0.88	1.38	0.42
5	1.10	1.70	0.61

Figure 53 Flow velocity and pressure drop per ft of straight copper pipe for a 50/50 glycol:water mix at 122°F (50°C)

5.4.5 Pressure drop of the selected solar storage tank

The pressure drop of the solar storage tank depends on the number of collectors and the flow rate. The indirect coils of the solar storage tank have various pressure drop characteristics because of their differing dimensions. Use

Figure 54 to estimate the pressure drop. The pressure drop in the table applies to a 50/50 glycol:water mixture at a temperature of 122 °F (50 °C).

Number of collectors	Flow rate gpm	Pressure drop in solar indirect coils of the storage tank	
		SOL-RET80 in feet of head	SOL-RET120 in feet of head
2	0.44	0.6'	0.8'
3	0.66	0.8'	1.1'
4	0.88	1.2'	1.4'
5	1.1	1.3'	1.6'

Figure 54 Pressure drop values of solar storage tanks for a 50/50 glycol:water mixture at 122°F (50°C)

5.4.6 Bosch KS0105 pump station

The pump station needs to overcome the following pressure drops:

- Pressure drop in the collector array
- Pipework pressure drop
- Pressure drop in the solar storage tank
- Additional pressure drop due to heat meter, valves or other fittings

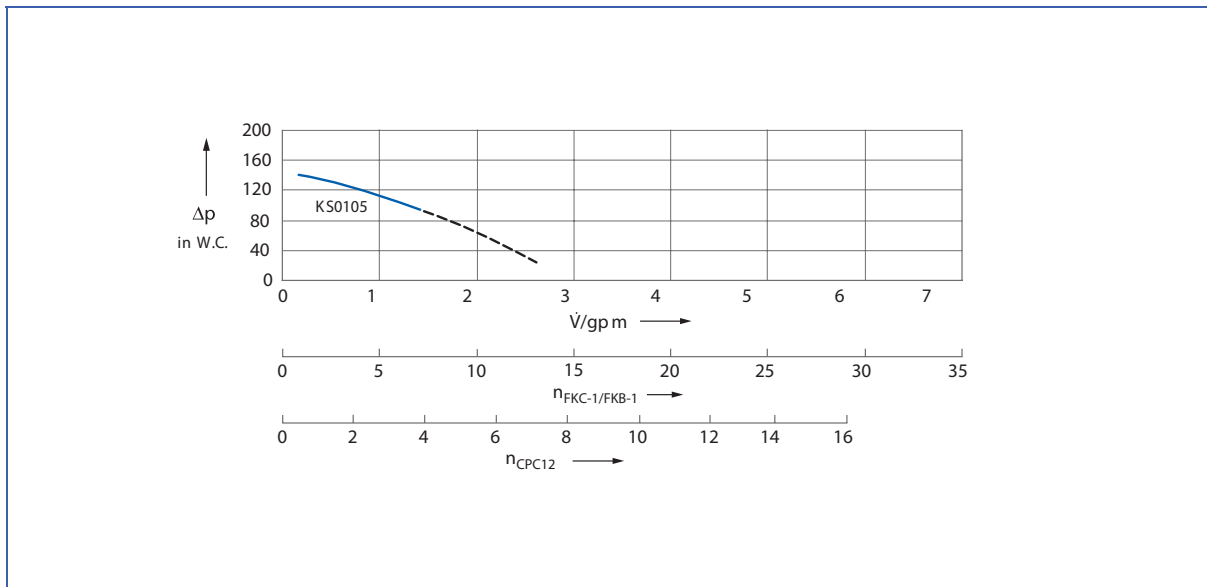


Figure 55 Pressure ranges of the Bosch KS0105 pump stations subject to the flow rate and number of collectors flow limiter display range highlighted in blue

5.5 Sizing of the diaphragm expansion vessel (DEV)

5.5.1 System volume calculation

The volume of a solar system with the Bosch KS0105 pump station is significant for sizing the expansion vessel and determining the volume of solar fluid.

The following formula applies to the filling volume of the solar system with a Bosch KS0105 pump station:

$$V_A = V_K \cdot n_K + V_{WT} + V_{KS} + V_R$$

Figure 56 Formula for filling volume of solar heating systems with Bosch KS0105 pump station

Calculating sizes

V_A	System filling volume
V_k	Volume of one collector
n_k	Number of collectors
V_{WT}	Solar indirect coil volume
V_{ks}	Volume of a Bosch KS0105 pump station (approx. 1/4 gal (1 l))
V_R	Pipework volume

Pipe dimension Ø × wall thickness in	Specific line volume gallons per foot (l/ft)
1/2"	0.0121 (0.0450)
3/4"	0.0251 (0.0950)
1"	0.0429 (0.1624)

Figure 57 Specific filling volume of selected pipework

Solar collectors			Collector content gallons (liters)
Type	Version		
Flat-plate collector	FKC-1	vertical	0.23 (0.86)
		horizontal	0.33 (1.25)
Flat-plate collector	FKB-1	vertical	0.23 (0.86)

Figure 58 Filling volume of Bosch solar collectors

5.5.2 Diaphragm expansion vessel for solar systems

Calculation principles

Precharge

Adjust the precharge of the diaphragm expansion vessel (DEV) prior to filling the solar system. The required system precharge is calculated using the following formula:

$$p_V = 0.442 \cdot h_{stat} + 5.8\text{psi}$$

Figure 59 Formula for inlet pressure of a diaphragm expansion vessel

Calculation parameters (Figure 59) and picture legend (Figure 60)

p_V	DEV inlet pressure in bar
h_{stat}	Static height in ft between center of DEV and highest point of system

The minimum precharge is 17.4 psi (1.2 bar).

Filling pressure

The expansion vessel creates an equilibrium between the fluid pressure and the gas pressure. The equilibrium (V_V Figure 64) is set with the system cold and monitored via the pressure gauge after bleeding the air from the system. The system pressure should be dialed in at 5 psi above the DEV preset pressure. A controlled evaporation temperature of 250 °F (120 °C) is therefore reached in the event of stagnation.

The filling pressure is calculated using the following formula:

$$p_0 = p_V + 5\text{psi}$$

Figure 61 Formula for filling pressure of a diaphragm expansion vessel

Calculation parameters (Figure 61) and picture legend (Figure 62)

p_0	DEV filling pressure in psi
p_V	DEV precharge pressure in psi
V_V	Membrane

A deviation from the optimum precharge pressure or filling pressure always leads to a reduction in available volume. This can cause system malfunctions, like early stagnation, or fluid spills from the relief valve.

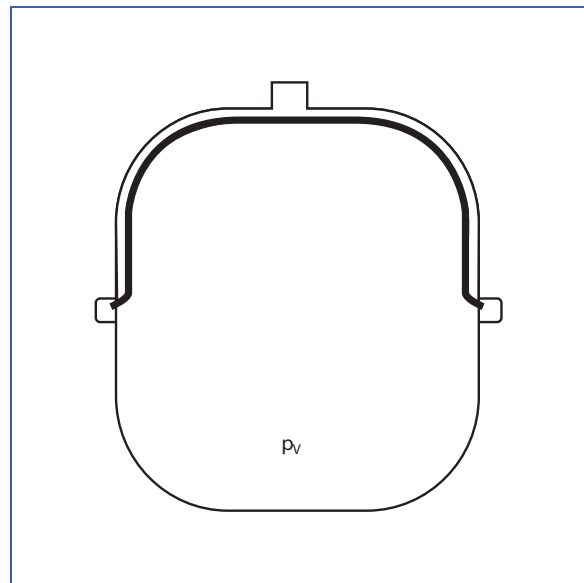


Figure 60 In a precharged diaphragm expansion vessel that is disconnected from the system the membrane will fill the entire space

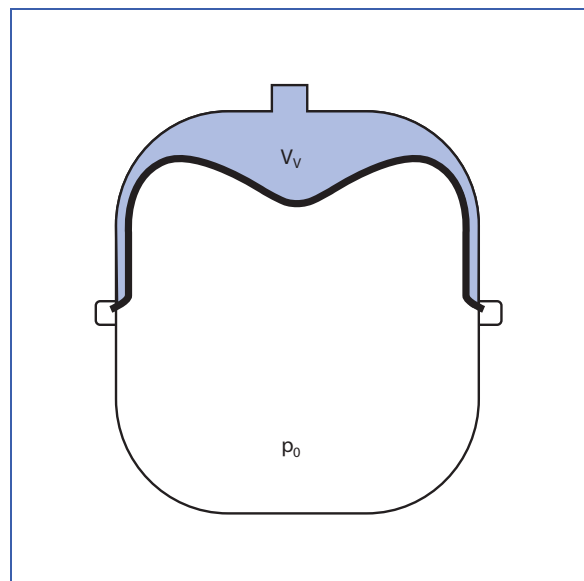


Figure 62 Filling pressure of a diaphragm expansion vessel

Operating pressure

At the maximum collector temperature, the filling gas is compressed to the final system pressure by taking up additional expansion volume (Figure 64).

The final pressure of the solar system and the pressure rating and the required size of the DEV are determined by the safety valve response pressure. The final pressure is determined using the following formula:

$$p_e \leq p_{SV} - 3\text{psi} \quad \text{for} \quad p_{SV} \leq 44\text{psi}$$

$$p_e \leq 0.9 \cdot p_{SV} \quad \text{for} \quad p_{SV} > 44\text{psi}$$

Figure 63 Formula for final pressure of a diaphragm expansion vessel subject to the safety valve response pressure

Calculation parameters (Figure 63) and picture legend (Figure 64)

p_e	DEV final pressure in psi
p_{SV}	Safety valve response pressure in psi
V_e	Expansion volume
V_V	Hydraulic seal

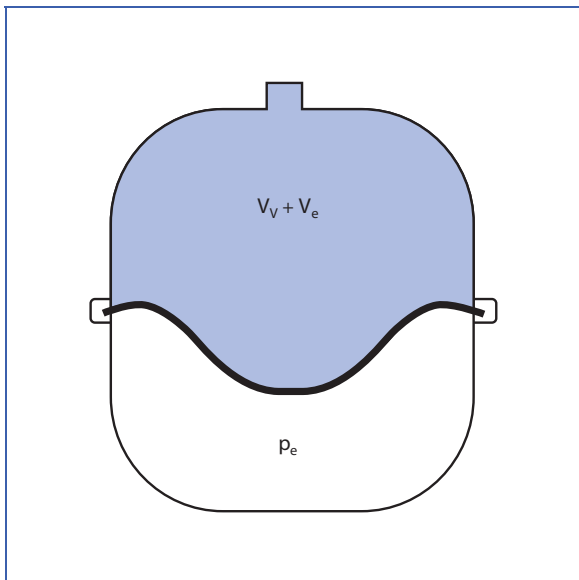


Figure 64 Final pressure of diaphragm expansion vessel

Intrinsic safety of a solar system

A solar system is considered to be intrinsically safe if the DEV can absorb the volume change as a result of solar fluid evaporation in the collector and the connecting lines (stagnation). If a solar system is not intrinsically safe, the safety valve responds during stagnation resulting in loss of fluid and pressure. Afterwards the solar system has to be re-started and must be properly balanced to avoid future service interruptions.. A DEV is sized on the basis of the following assumptions and formula:

Calculation parameters (Figure 65 and 66)

$V_{n,min}$	Minimum D volume in gallons
V_A	System filling volume in gallons
n	Expansion coefficient (= 7.3% with $\Delta = 180^\circ\text{F}$ (100°C))
V_D	Evaporation volume in gallons
p_e	DEV outlet pressure in psi
p_o	DEV filling pressure in psi
n_k	Number of collectors
V_k	Volume of collectors

$$V_{n,min} = (V_A \cdot n + V_D) \cdot \frac{(p_e + 14.7)}{(p_e - p_o)}$$

Figure 65 Formula for minimum DEV volume

$$V_D = n_k \cdot V_k$$

Figure 66 Formula for evaporation volume

5.6 Sizing swimming pool water heating systems

The weather conditions and the swimming pool heat loss into the ground have a considerable influence on sizing. For that reason, sizing a solar heating system for heating swimming pool water can only ever be approximate. Basically, the sizing has to be oriented to the area of the pool. The water cannot be guaranteed to be at a certain temperature over several months. If the solar swimming pool water heating system is combined with DHW heating, we recommend the use of a dual-mode solar heating storage tank with a large solar indirect coil and limited storage tank heating up to 140 °F.

Standard values for indoor swimming pools with covers

Conditions for standard indoor swimming pool values

- Pool basin covered when not in used (insulation)
- Set pool water temperature 75 °F

If the required set water temperature is higher than 75 °F, the number of required collectors increases by the correction factor listed below

Range	Reference size	Sizing with solar collectors
		FKC-1
Pool surface	Pool surface in ft ²	1 collector for every 50 ft ²
Correction factor for pool water temperature	Deviation above 75 °F pool water temperature	1.3 additional collectors for every +1 °F above pool water temp of 75 °F

Example

- Parameters
 - Indoor swimming pool, covered
 - Pool surface 350 ft²
 - Pool water temperature 76 °F
- Wanted
 - Number of FKC-1 solar collectors for solar swimming pool water heating
- Read above table
 - 5 FKC-1 solar collectors for pool area of 350 ft²
 - 1 FKC-1 solar collector as correction for +1 °F above 75 °F pool water temperature

Six FKC-1 solar collectors are required for solar swimming pool water heating.

Standard values for outdoor swimming pools

The standard values only apply if the swimming pool is insulated and embedded in the ground in a dry condition. First insulate the pool if the swimming pool is at the level of groundwater without insulation. Then carry out a heat demand calculation.

Covered outdoor swimming pool (or indoor swimming pool without insulation)

A ratio of 1:2 applies as standard value. This means that the area of a collector array with the FKC-1 must be half the size of the pool surface area.

Outdoor swimming pool without insulation

In this case the standard value ratio is 1:1. This means that the area of a collector array comprising FKC-1 collectors must be the same size as the pool surface. If the solar heating system is intended for an outdoor swimming pool, DHW heating and/or central heating backup, add the required collector areas for the swimming pool water and DHW. Do not add the collector areas for central heating. The solar heating system heats the outdoor swimming pool in summer and central

6 Design/engineering information regarding installation

6.1 Pipework, thermal insulation and collector temperature sensor extension cable

Glycol and temperature-resistant sealing

All components of a solar system (including flexible gaskets for valve seats, diaphragms in expansion vessels etc.) must be made from glycol-resistant materials and carefully sealed, since water:glycol mixtures have a greater tendency to leak than pure water. Aramide fiber seals have proven to be effective. Graphited cord is suitable for sealing glands. Hemp seals must also be coated with temperature-resistant and glycol-resistant thread paste. Nissen products “Neo Fermit universal” or “Fermitol” can be used as thread paste (follow the manufacturer’s instructions).

The solar hose ferrules on the Bosch FKC-1 and FKB-1 collectors provide an easy and reliable seal for collector connections. Connecting kits for 1/2 inch Twin-Tube are available for providing a reliable connection to the Twin-Tube double tube.

Pipework routing

All connections in the solar circuit that do not have Bosch-supplied compression fittings must be soldered or brazed. Alternatively, compression fittings or press fittings can be used, provided that they are suitable for use with a water:glycol mixture and respectively high temperatures of up to 400 °F (205 °C). All pipework must be routed with a rise towards the collector array or the air vent valve, if installed. Heat expansion must be taken into consideration when routing the pipework.

The pipes must be routed with provisions for expansion (bends, sliding clamps, compensators) to prevent damage and leaks.

Plastic pipework, PEX, or galvanized components are not suitable for solar systems.

Thermal insulation

Connection lines may be routed in unused flues, air ducts and wall cavities (in new buildings). Open ducts must be properly sealed to prevent heat loss caused by rising air (convection). Follow building codes when penetrating floors.

The thermal insulation of the connection lines must be designed for the operating temperature of the solar system. Therefore use appropriate high temperature-resistant insulating materials such as insulating hoses made from EPDM rubber. Thermal insulation exposed to the elements on the roof must be UV, weather and temperature resistant.

Figure 67 shows standard values for the insulating thickness on pipework in solar systems. Mineral wool is not suitable for outdoor applications because it absorbs water and then fails to provide thermal insulation.

Pipe diameter inches	Twin-Tube (double tube) insulation thickness inches	Aeroflex SSH pipe diameter × insulation thickness inches	Aeroflex HT pipe diameter × insulation thickness inches	Mineral wool insulation thickness (indoor application only) inches
1/2	1/2"	–	1/2 x 1"	3/4"
5/8	–	5/8 x 1"	5/8 x 1"	3/4"
3/4	1/2"	1 x 1"	1 x 1"	3/4"
1	–	1 x 1"	1 x 1"	3/4"
1-1/4	–	1-1/4 x 1-1/2"	1 x 1-1/2"	1-3/16"
1-1/2	–	1-1/2 x 1-1/2"	1-1/2 x 1-1/2"	1-3/16"

Figure 67 Thickness of thermal insulation for solar system connection lines.

Collector temperature sensor extension lead

When routing the pipework, also route a two-core lead (up to 164 ft length 18 AWG) for the collector sensor alongside. An appropriate lead is provided in the insulation of the Bosch Twin-Tube. Provide a shield for the collector

temperature sensor extension lead, if it is routed next to a 120 V cable. Install the FSK collector temperature sensor in the sensor well of the top supply header of the Bosch FKC-1 and FKB-1 collectors.

6.2 Air vent valve

6.2.1 Automatic air vent valve

Unless a high volume and high pressure filling station with air separator is being used, solar systems with flat-plate collectors are vented via quick-acting air vent valves at the highest point of the system. After filling has been completed, this valve must be closed and remain closed to prevent steaming solar fluid from escaping from the system in the event of stagnation.

Provide an air vent valve at the highest point of the system (detail E, Figure 68) and, for every change of direction, with a new rise (e.g. in dormers, Figure 44). If there are several rows of collectors, provide an air vent valve for each row (Figure 69), unless the system can be vented above the top row (Figure 70). Use only automatic all-metal air valves.

Never use air vent valves with plastic floats in solar heating systems because of the high temperatures that occur. If there is insufficient room for an automatic all-metal air vent valve with an upstream ball valve, install a manual air vent valve.

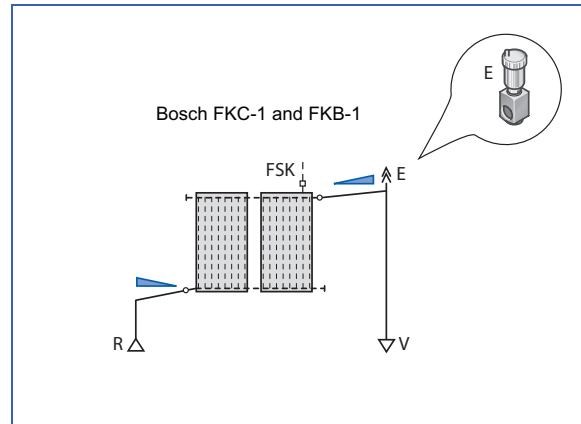


Figure 68 Hydraulic diagram with air vent valve at the highest point of system

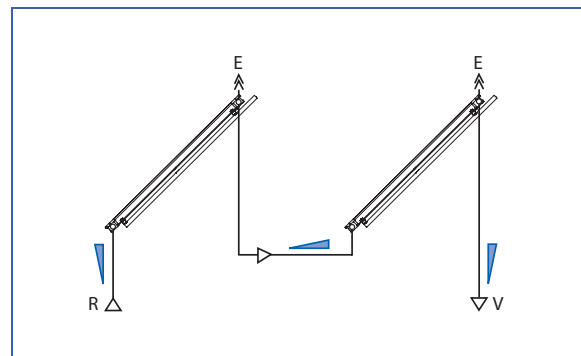


Figure 69 Hydraulic diagram with air vent valve for each collector row on the example of flat roof installation (connection in series)

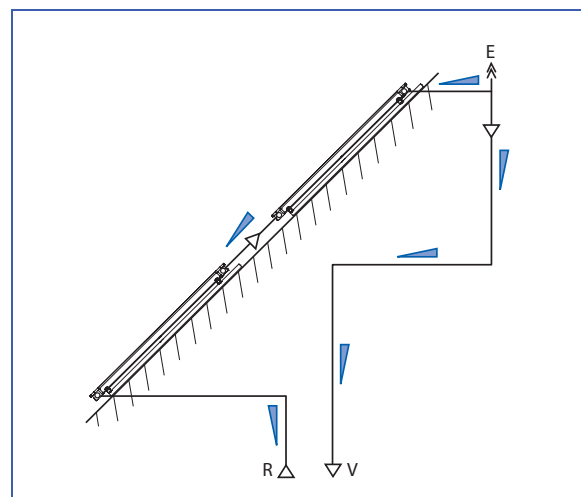


Figure 70 Hydraulic diagram with air vent valve above the top row on the example of rooftop installation (connection in series)

6.2.2 Filling station and air separator

The quickest and most efficient way to fill Bosch solar systems is by using the Bosch filling station (Figure 71), resulting in most air being pushed out of the system during the filling procedure. An air vent valve on the roof is not needed in this case.

Benefits of the system are:

- Reduced installation effort because no air vent valves are needed on the roof
- Easy and quick commissioning, i.e. filling and deaeration in one step, followed by pressurization.
- Efficiently vented system
- Low-maintenance operation

If the collector array consists of several rows connected in parallel, provide each individual row with a shut-off valve in the supply pipe. Each row is filled and vented individually during the filling procedure.

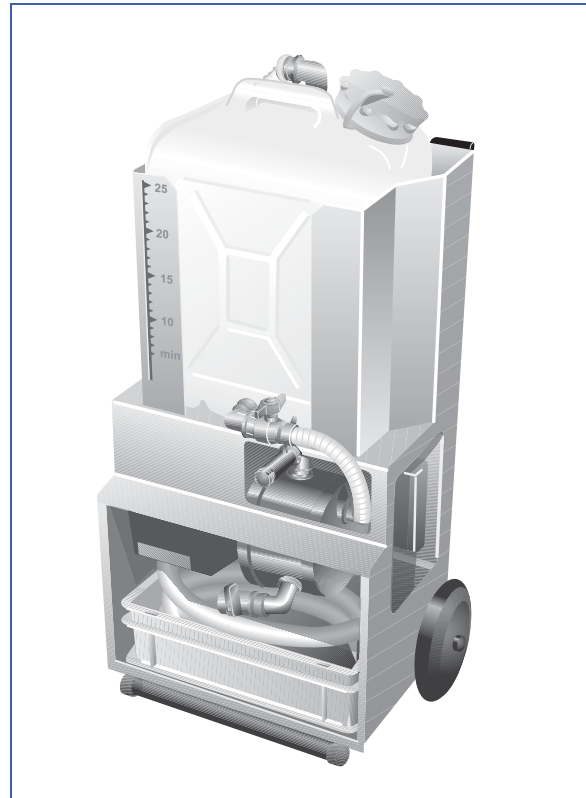


Figure 71 Bosch solar filling station

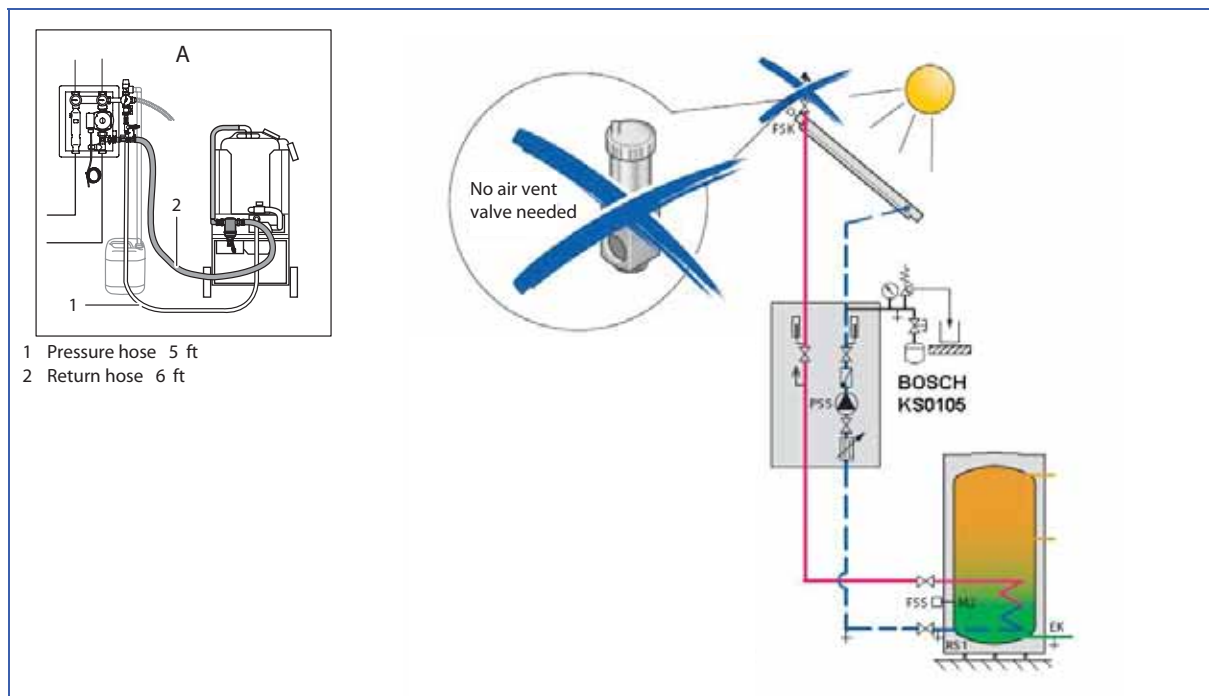


Figure 72 System design; detail A: Filling procedure with pump

6.3 Roof mounting systems

6.3.1 Permissible standard snow loads and building heights

The following table contains the permissible standard snow loads and building heights for the different installation options. This information is most useful during the planning phase of a solar thermal project.

	Rooftop installation Vertical/horizontal	Flat roof installation Vertical/horizontal	Wall mounting 45–60 Horizontal
Roof cover/wall	Tiles, plain tiles, slate, shingle, corrugated sheets, sheet steel, bitumen	–	load-bearing
Permissible roof pitch	25°–65°, 5°–65° (corrugated sheets, sheet steel roof)	0° (with slightly sloping roofs of up to 25°, protection from sliding off or on-site attachment)	–
Permissible building heights (wind loads) of up to 65 ft - at wind speeds of up to 80 mph	Without accessories	Without accessories (observe securing flat roof supports!)	Without accessories
Permissible building heights (wind loads) of up to 300 ft - at wind speeds of up to 94 mph	Only vertical collectors with rooftop installation kit	With flat roof support kit (observe flat roof support fixing!)	Not permissible
Standard snow loads 0–2.5 lbs/ft ²	Without accessories	Without accessories	Without accessories
Standard snow loads > 2.5 lbs/ft ²	Only vertical collectors with rooftop installation kit up to 35 lbs/ft ²	Without flat roof support kit up to 43 lbs/ft ²	Not permissible

Figure 73 Permissible standard snow loads and building heights

6.3.2 Rooftop installation

The collectors are secured directly to the roof at the same pitch of the roof itself.

The rooftop installation kit for Bosch FKC-1 and FKB-1 flat-plate collectors consists of a standard kit for the first collector in a row and an extension kit for each additional collector in the same row (Figure 74). Use the rooftop installation extension kit only in conjunction with a standard kit. In place of the single-side collector clamps (item 1 Figure 75) the extension kit contains so-called double-sided collector clamps (item 5 Figure 75) and connectors for defining the correct spacing and securing two adjacent Bosch FKC-1 or FKB-1 flat-plate collectors.

Roof connections for different roof covers

The profile rails and collector tensioners of the various rooftop installation kits are identical for all roof connections. The various installation kits for tile and plain tile, slate and shingle cover as well as for corrugated sheet and sheet steel roofs only differ with regard to the type of roof hook (Figure 74) or special attachment materials used (Figure 75).

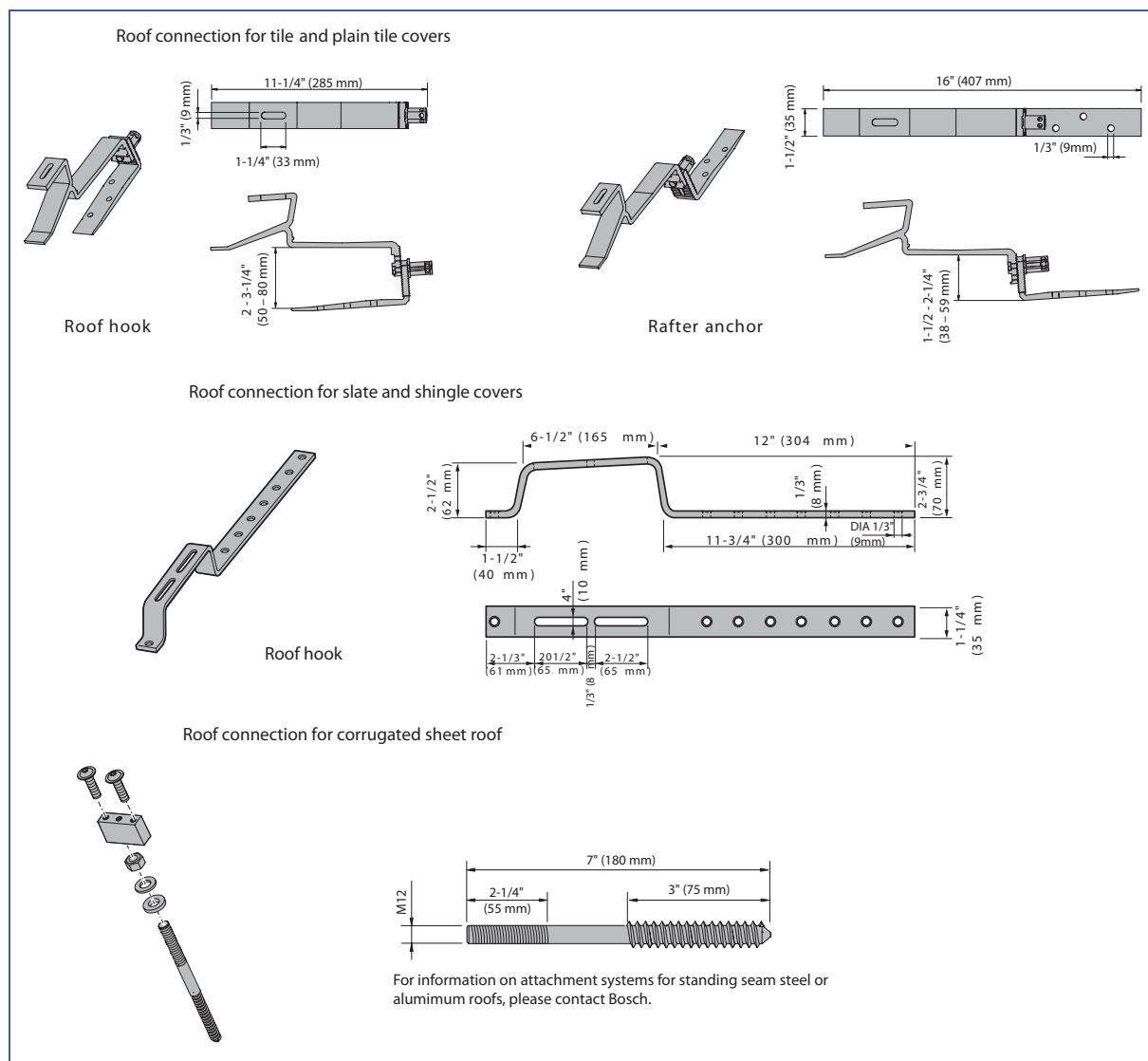


Figure 74 Roof connection versions for different roof covers (dimensions in inches (mm))

Roof connection for tiled roofs

Figure 75 shows an example for a rooftop installation on a tile roof. On roofs with simple battens, the roof jacks are fastened to the sheathing (Figure 76). This is done by turning the lower part of the roof jack over. If additional height compensation is needed, the lower section of the roof jack can be shimmed up. On roofs with counter battens, the roof jacks (Figure 74) are hooked over the existing roof battens (Figure 76) and fastened to the profile rails.

When considering installation on a tile roof, check whether the dimensions specified in Figure 75, detail A, can be met. Use the roof jacks supplied, if they

- fit into the valley of the roof tile and
- extend over the roof tile plus roof batten.

The tile cover should not exceed 5 inches. Where necessary, include a roofing contractor in the planning and installation process. Care must be taken that the hooks are only mounted on parts of the roof that are capable of providing the necessary support under all foreseeable conditions.

Legend (Figure 75)

- 1 Single-sided collector tensioner (only in the standard kit)
- 2 Roof jack, adjustable
- 3 Profile rail
- 4 Collector hook (2x per collector)
- 5 Double-sided collector clamp (only in the extension kit)
- 6 Connector (only in the extension kit)
- 7 Sheathing

Legend (Figure 76)

- 1 Hex nut
- 2 Serrated washer
- 3 Roof batten
- 4 Roof jack, lower part

Legend (Figure 77)

- 1 Hexagon nut
- 2 Serrated washer
- 3 Wood screws
- 4 Roof jack, lower part
- 5 Sheathing

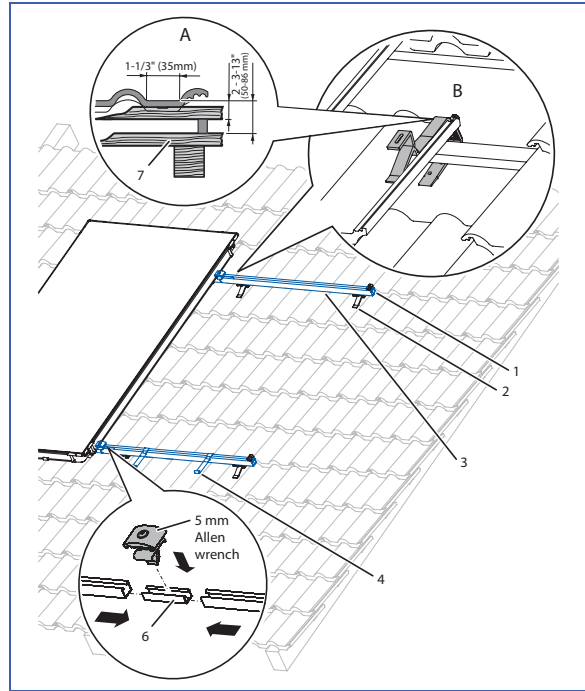


Figure 75 Rooftop installation standard kit and extension kit (highlighted in blue) for one Bosch FKC-1 and FKB-1 flat-plate collector (detail A: dimensions in inches (mm))

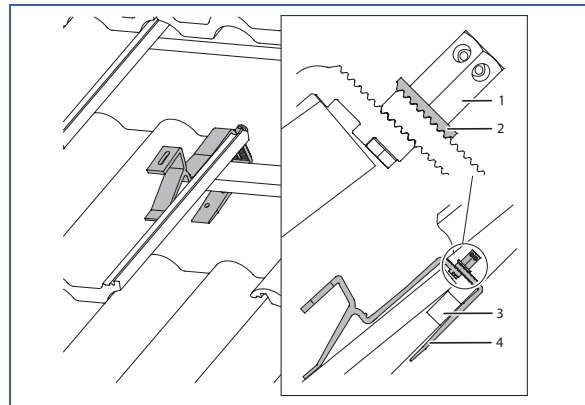


Figure 76 Installed roof jack

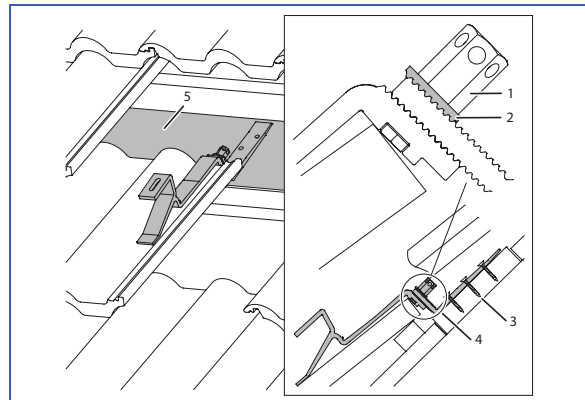


Figure 77 Roof jack fastened to the sheathing

Plain tile roof connection

Figure 78 shows attaching the roof jack (item 2) to a plain tile roof. Trim and attach the plain tiles on site.

The horizontal profile rails are fastened to the roof jack the same way as with regular tiles (Figure 75).

Consult a roofing contractor for rooftop installation on plain tiles, if needed.

Legend (Figure 78)

- 1 Plain tiles (cut along the dotted line)
- 2 Roof hook, lower part fastened to sheathing

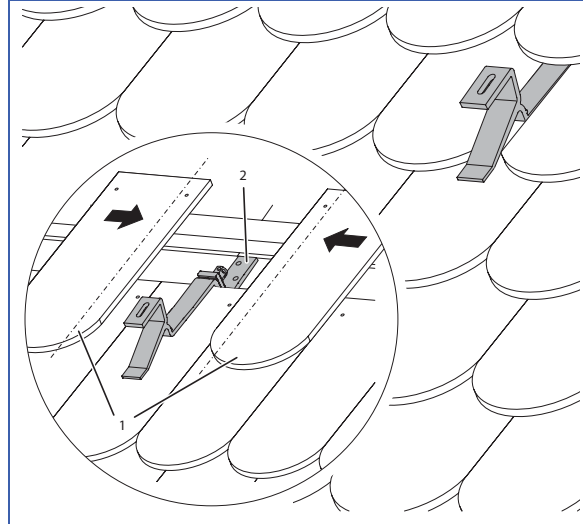


Figure 78 Roof jack attached on a plain tile roof

Roof connection with slate or shingle

Roof jack installations on slate or shingle roofs should be carried out by a roofing contractor.

Figure 79 shows an example of an installation of the roof jacks (item 5 Figure 79) on a slate or shingle roof. Gaskets, caulking and flashing to be provided on site. The horizontal profile rails are to be fastened to the roof jacks in the same way as on a tile roof (Figure 75).

Legend (Figure 79)

- 1 Flashing top (on site)
- 2 Flashing bottom (on site)
- 3 Overlapping shingle or slate
- 4 Gasket or caulking (on site)
- 5 Roof jack
- 6 Screw (provided)

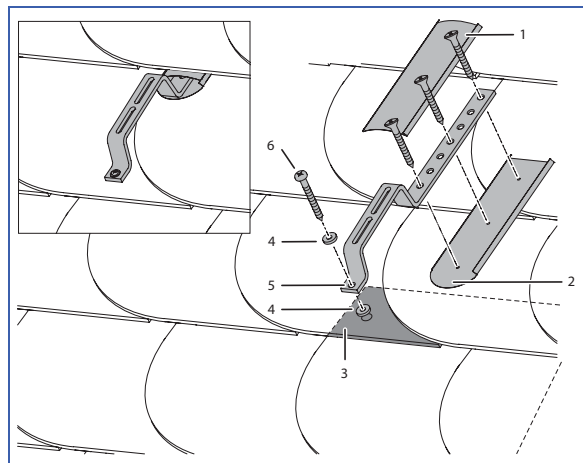


Figure 79 Special roof jack with waterproof cover (optional) for attaching a rooftop installation kit for flat-plate collectors to a slate or shingle roof

Roof connection in situations with added insulation on rafters

Figure 80 shows a scenario with insulation on rafters using the roof hooks. In order to establish an adequate base to attach the roof hooks to, the roofing contractor secures wooden boards with a minimum cross-section of 1 x 8 inches to the rafters. The force generated by the roof hook must be transferred by this board to the loadbearing rafters. With an assumed maximum snow load of 42 lbs/ft² (without accessories) or 65 lbs/ft² (with accessories), the design must be able to safely bear the following loads:

- Force parallel to the roof surface: $F_{SX} = 180 \text{ lbf}$
- Force perpendicular to the roof surface: $F_{SY} = 400 \text{ lbf}$

The horizontal profile rails must be fastened to the special roof jacks in the same way as they are with a tile roof (Figure 75).

Legend (Figure 80)

- 1 Roof tile
- 2 Roof jack
- 3 Insulation on rafters
- 4 Rafter
- 5 Adequate screw for load (provided on site)
- 6 Board (at least 1 x 8 inches)

F_{SX} Load parallel to the roof surface

F_{SY} Load perpendicular to the roof surface

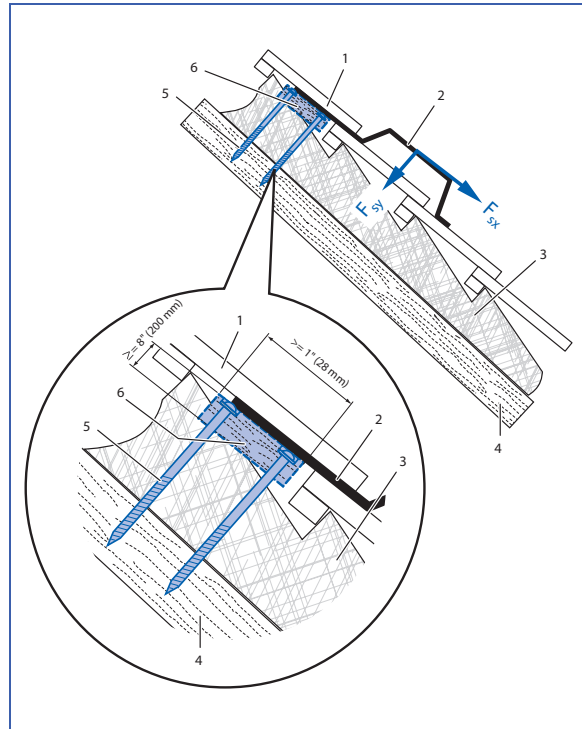


Figure 80 Example of on-site attachment of additional boards on top of insulation on rafters. Design may vary based on conditions. Use of a roofing contractor highly recommended.

Attachment on corrugated sheet roofs

Installation on a corrugated sheet roof is only possible if the headless screws can be fastened at least 1½ inches into a structural element with adequate load-bearing capacity (Figure 81).

The corrugated sheet roof connection kit contains headless screws including retaining brackets and gaskets that are used instead of the roof jacks in the rooftop installation kit.

Figure 83 shows how the profile rails are attached to the retaining brackets of the screws.

Legend (Figure 81)

- 1 M8 x 16 Allen screws
- 2 Profile rail
- 3 Retaining bracket
- 4 Hex nut
- 5 Gasket

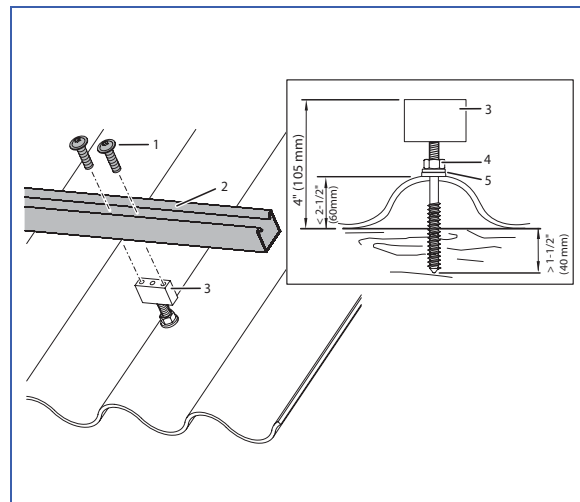


Figure 81 Example of profile rail attachment with rooftop installation on a corrugated sheet roof. Use of a roofing contractor is highly recommended

Installation on standing seam steel or aluminum roofs

Contact our solar supplier or Bosch Solar for special attachment clamps for standing seam metal roofs.

<http://www.boschsolar.com/>

Connection on flat seam metal roofs

Figure 88 shows a mounting option for metal roofs without standing seams. It is recommended to consult a roofing contractor as the roof's membrane has to be penetrated.

Secure a sleeve similar to the one shown in Figure 82 to the roof on site and use appropriate measures to waterproof the penetration. Choose the number of sleeves per collector based on their load rating, but at least four. Sleeves can also be soldered or brazed to the roof. The M12 × 180 screws are fastened to the substructure (rafter or load-bearing beam, at least 2 x 2 inches) through the sleeve.

Legend (Figure 82)

- 1 Profile rail
- 2 M8 × 16 Allen screws
- 3 Retaining bracket
- 4 M12 screw
- 5 Sleeve
- 6 Sheet metal roof
- 7 Load bearing sub-structure (minimum 2 x 2 inches)

Consult a roofing contractor to ensure a weather proof installation and avoid water damage to the building.

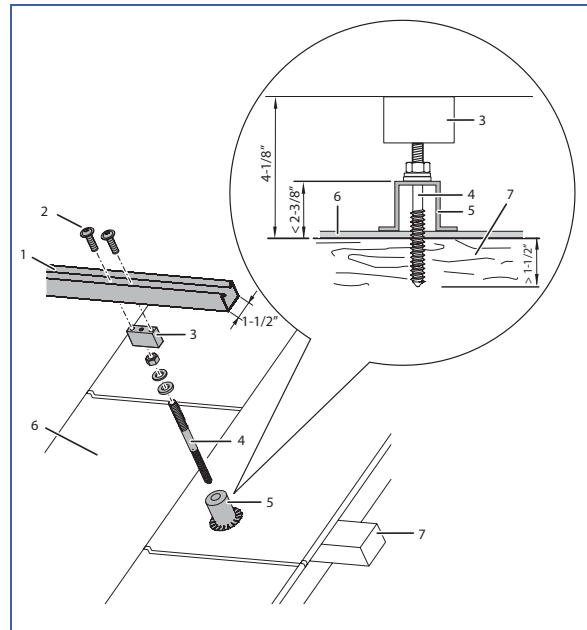


Figure 82 On-site attachment of sleeves for watertight mounting of screws for installation on sheet metal roofs (dimensions in inches)

Snow load profile/additional rail

Install a snow guard and an additional rail (accessories) on buildings between 65 ft and 300 ft in height and in regions with snow loads of 42 lbs/ft² to 65 lbs/ft². These provide better distribution of the higher loads on the roof.

Figure 83 shows the installation of a snow guard and an additional rail on the example of tile cover. Both accessories can also be fitted to installation systems for other roof types.

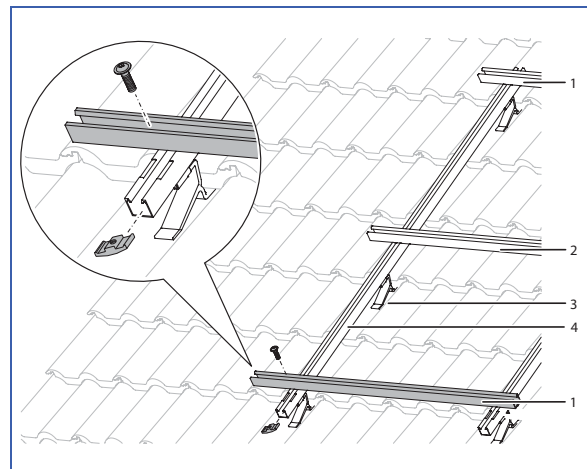


Figure 83 Rooftop installation kit with snow guard and additional rail

Legend (Figure 83)

- 1 Profile rails types (rooftop installation kit)
- 2 Additional rails (including collector tensioner)
- 3 Additional roof connection (snow guard standard delivery)
- 4 Vertical profile rails (snow guard standard delivery)

Hydraulic connections

The rooftop connection kits are used to make the hydraulic collector connections (Figure 84).

It is recommended to penetrate the roof close to the collector connection, and avoid long pipe runs above the roof.

For asphalt shingle roofs use standard plumber’s rubber pipe flashing.

It is recommended to consult a roofing contractor for specifics and to avoid water damage to the building. Roof outlets are required for supply and return, since the collector connections are above roof level. On tile roofs a “ventilation tile” (Figure 85) can be used as a roof outlet for the supply and return lines. If the site allows, and an air vent is needed (-> 6.2), mount the air vent in the attic. Ensure still that it marks the highest point of all piping, and is mounted perfectly vertical to ensure proper operation of the internal float. The supply line is routed through the roofing skin with an incline to the air vent valve, if required, via the upper ventilation tile. The lead from the collector temperature sensor also runs through this tile. Route the return line to the pump station. A plumber’s rubber pipe flashing or ventilation tile can be used for this if the return line runs in the attic (Figure 85). An additional air vent valve is not usually required, in spite of the change of direction at the penetration.

Involve a roofing contractor in the planning to prevent damage to the building.

Legend (Figure 84)

- 1 Connecting line 39 inches
- 2 Dummy plug
- 3 Spring clips
- 4 Hose coupling with R 3/4 inch connection or 5/8 inch locking ring

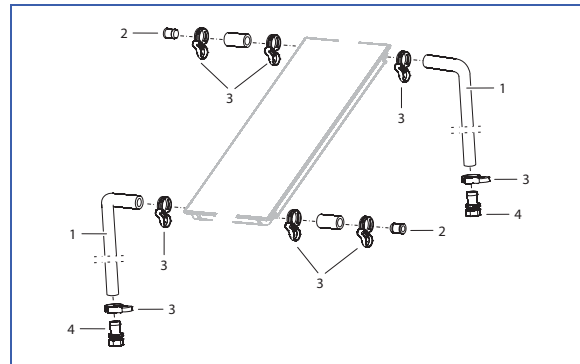


Figure 84 FKC-1 and FKB-1 rooftop connection kit

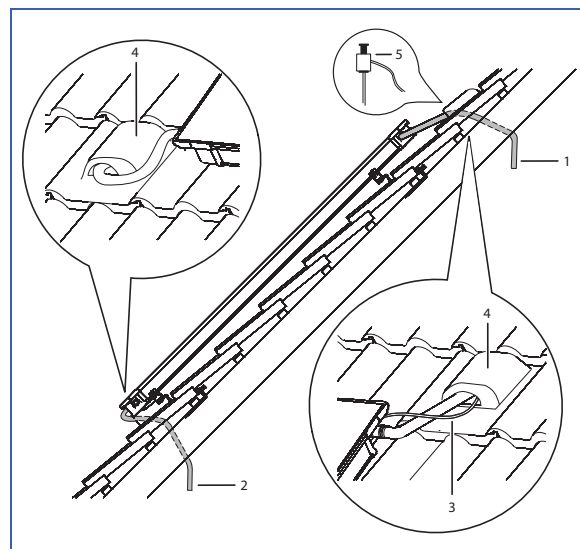


Figure 85 Ventilation tile example

Legend (Figure 85)

- 1 Supply line
- 2 Return line
- 3 Sensor lead
- 4 Ventilation tile
- 5 Air vent valve

Static requirements

The rooftop installation kit is exclusively designed for the secure mounting of solar collectors. Never attach other rooftop equipment such as antennae to the collectors or collector mounting kits.

The roof and the substructure must have an adequate load-bearing capacity. A load of about 100

lbs can be expected for each Bosch FKC-1 or FKB-1 flat-plate collector. Also take the specific regional loads resulting from wind, snow and other factors into account.

The values in Figure 86 are standard snow loads and building heights for rooftop installation.

Rooftop installation system component selection aid

Include appropriate connection materials in the design based on the number of collectors and their hydraulic connections.

		Total number of collectors		2			3			4		5	
		Number of rows		1	2	1	2	3	1	2	1	2	
		Number of collectors per row		2	1	3	2	1	4	2	5	3	
							1				2		
FKB-1 and FKC-1 portait	Standard kit ¹⁾	Tiles Plain tiles											
		Slate and asphalt shingle	1	2	1	2	3	1	2	1	2		
		Corrugated sheet Sheet metal roof											
	Extension kit ¹⁾	Tiles Plain tiles											
		Slate and asphalt shingle	1	-	2	1	-	3	2	4	3		
		Corrugated sheet sheet metal roof											
	Additional kit Standard kit ²⁾	Tiles Plain tiles											
		Slate and asphalt shingle	1	2	1	2	3	1	2	1	2		
		Corrugated sheet Sheet metal roof											
	Additional kit Extension kit ²⁾	Tiles Plain tiles											
		Slate and asphalt shingle	1	-	2	1	-	3	2	4	3		
		Corrugated sheet Sheet metal roof											
FKC-1 landscape	Standard kit ¹⁾	Tiles Plain tiles											
		Slate and asphalt shingle	1	2	1	2	3	1	2	1	2		
		Corrugated sheet Sheet metal roof											
	Extension kit ¹⁾	Tiles Plain tiles											
		Slate and asphalt shingle	1	-	2	1	-	3	2	4	3		
		Corrugated sheet Sheet metal roof											

Figure 86 Installation materials for rooftop installation systems

- 1) Consisting of installation kit and roof connection
- 2) Consisting of snow guard and additional horizontal rail, required for snow loads of 42 lbs/ft² to 65 lbs/ft² or building heights of 65 ft to 300 ft

6.3.3 Flat roof installation

Flat roof installation is intended for level roof surfaces, or where the collectors are to be positioned at an angle steeper than the pitch of the roof (Figure 87).

The flat roof installation kit for Bosch FKC-1 and FKB-1 flat-plate collectors consists of a standard kit for the first collector in a row and an extension kit for each additional collector in the same row (Figure 95). Accessories are required for buildings more than 65 ft high, or with snow loads of > 42 lbs/ft² (Figure 73).

The angle of inclination of the flat roof support can be adjusted in steps of 5° as follows:

- Vertical flat roof support: 30° to 60° (25° by trimming the telescopic rail)
- Horizontal flat roof support: 35° to 60° (25° or 30° by trimming the telescopic rail)

The flat roof supports can be installed to the roof by means of weighting (ballast) or by attaching them to the roof substructure.

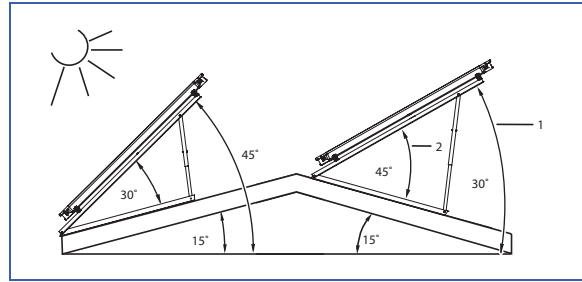


Figure 87 Examples of actual flat-plate collector angle of inclination when using flat roof supports on a flat roof with a shallow pitch (<25°)
Item1: pitch; Item2: collector angle of inclination

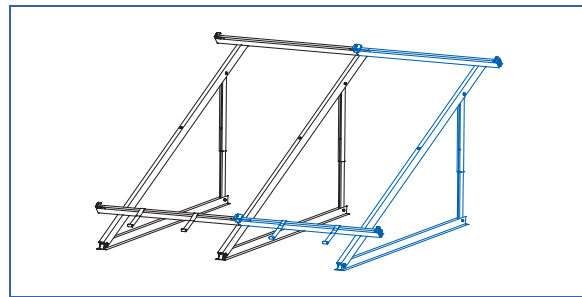


Figure 88 Flat roof support standard kit and extension kit (blue) for one FKC-1-s or FKB-1-s flat collector

On-site mounting

The flat roof supports can be mounted onto on-site substructures consisting of I-beams, for example (Figure 89). For this, predrilled holes are in the bottom profile rails of the flat roof supports. The on-site substructure must be designed such that the wind force acting upon the collectors can be absorbed. The support spacing dimensions can be found in figures 97 to 99. The positions of the holes for attaching the flat roof supports to the on-site substructure can be found in figure 100. For buildings more than 65 ft in height or with snow loads of 42 lbs/ft² to 80 lbs/ft², each standard kit for vertical collectors must be fitted with an additional rail (standard kit addition) and each extension kit must be fitted with an additional rail and an additional support (extension kit addition). With horizontal collectors, fit all installation kits with an additional rail (standard kit and extension kit addition).

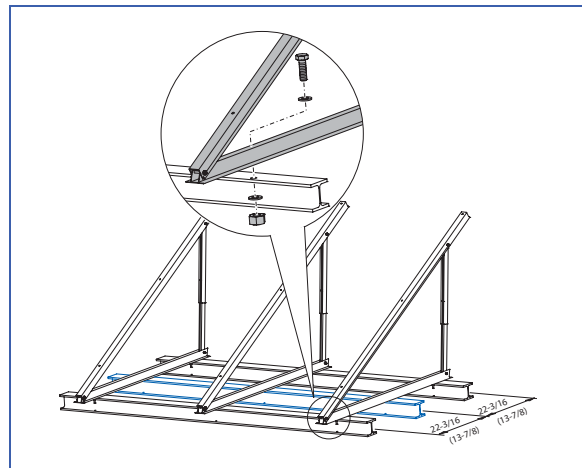


Figure 89 Flat roof support fixed on site with base anchoring to a substructure consisting of I-beam supports (dimensions in inches); value in brackets for horizontal version; center contact surface (blue) only required for buildings above 65ft in height.

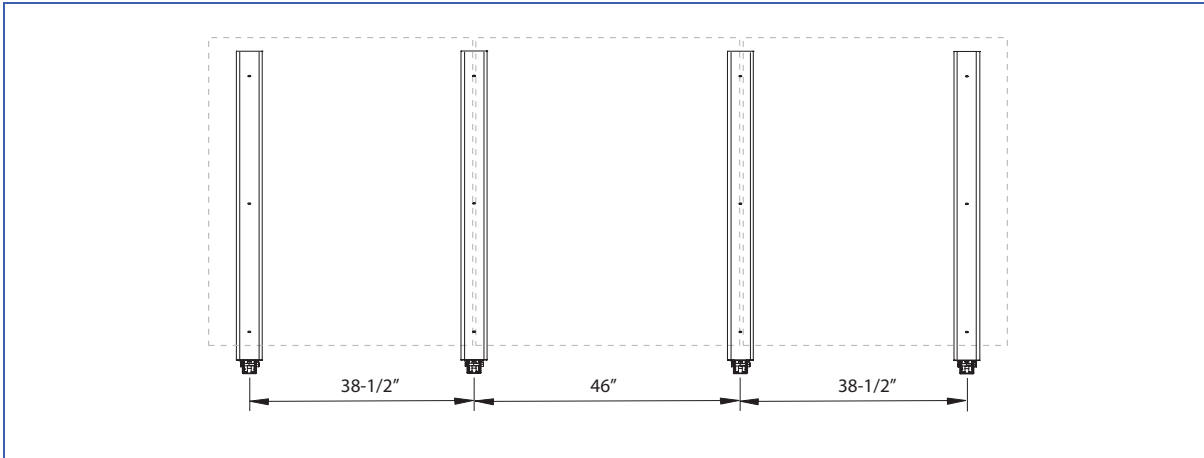


Figure 90 Collector support spacing in standard version with flat roof supports for vertical collectors FKC-1 and FKB-1 (dimensions in inches)

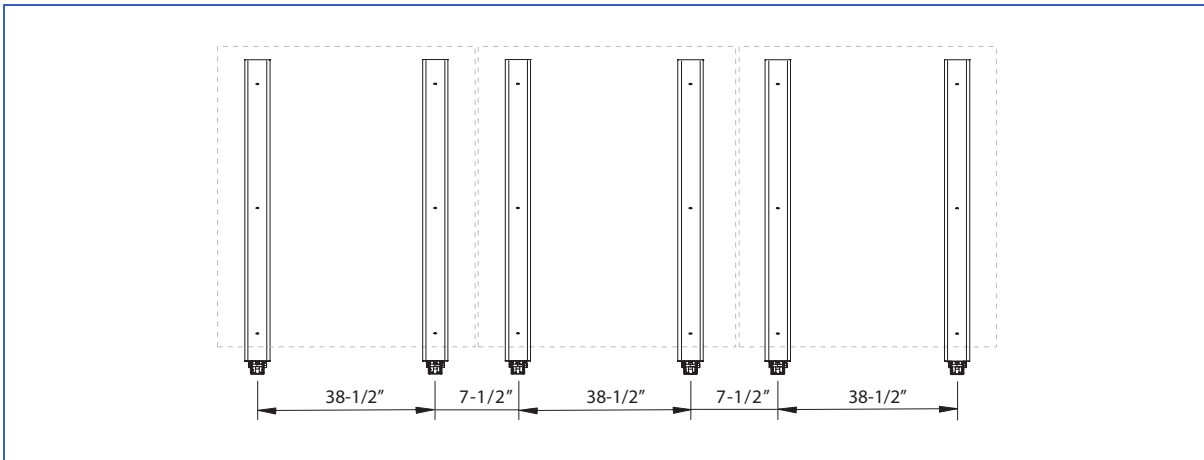


Figure 91 Collector support spacing in standard version when using additional supports with flat roof supports for vertical collectors FKC-1 and FKB-1 (dimensions in inches)

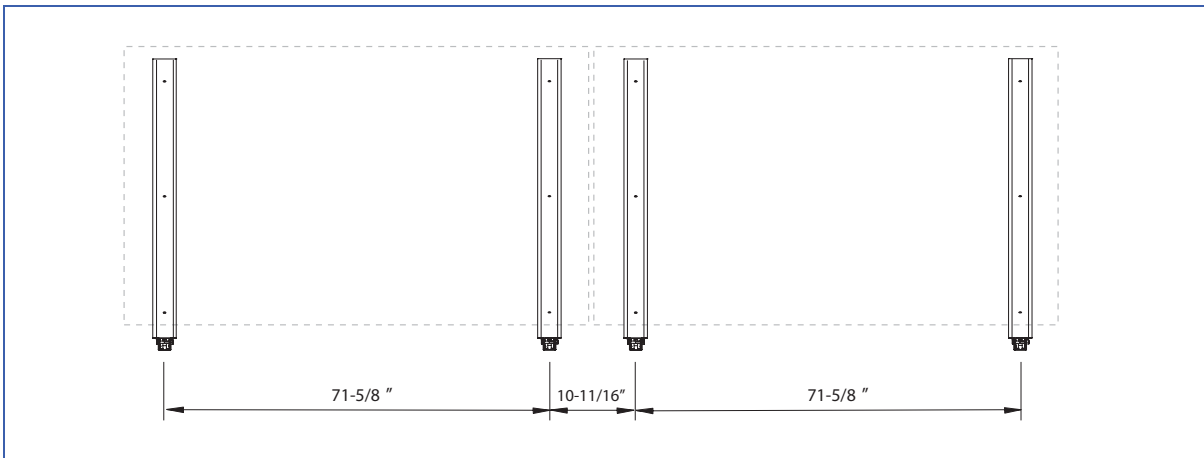


Figure 92 Distance between collector supports with flat roof supports for horizontal FKC-1 collectors (dimensions in inches)

Securing by means of ballast trays

Four ballast trays are required for each flat roof support when the collectors are weighed down (dimensions: 37-3/8" x 13-3/4" x 2") - these are hooked into the flat roof support (Figure 93) and must be filled with concrete bricks, gravel or the like. See Figure 96 for the required ballast weight (maximum 700 lbs with gravel filling) subject to the height of the building.

With a building up to 65 ft high and snow loads of up to 42 lbs/ft², one additional support is required for the 4th, 7th and 10th collector in a row when ballast trays are used in conjunction with vertical collectors. The installation kit includes one additional support when horizontal collectors are used. The additional supports are required for hooking in the trays.

For buildings higher than 65 ft or with snow loads of 42 lbs/ft² to 80 lbs/ft², each standard kit must include an additional rail (standard kit addition) and each extension kit for vertical collectors must include an additional support and an additional rail (extension kit addition). With horizontal collectors, all installation kits must be equipped with an additional rail (standard kit and extension kit addition). Erect the entire structure on protective building mats to protect the roof membrane. Ensure that the roof and building can support the weight of the collectors and ballast.

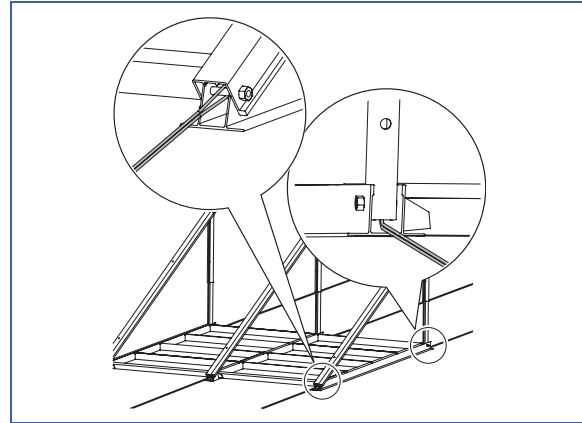


Figure 93 Flat roof support with ballast trays and additional guy ropes

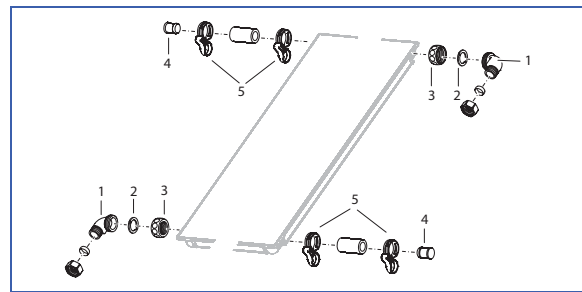


Figure 94 FKC-1 flat roof connection kit

Hydraulic connections

The flat roof connection kits are used to make the hydraulic collector connections in flat roof installation (Fig. 87). Route the supply line parallel to the collector to prevent damage to the connection due to the movement of the collector in the wind.

Static requirements

Follow Figure 73 snow loads and building heights.

Legend (Figure 94)

- 1 Bracket with R 3/4 inch connection on the system-side or 5/8 inch locking ring
- 2 Stop washer
- 3 Nut G1
- 4 Dummy plug
- 5 Spring clips

Legend (Figure 95)

- 1 Pipe clamp (on site)
- 2 M8 thread to attach hose clamp for routing pipe alongside the collector
- 3 Bracket (connection kit standard delivery)
- 4 Supply line

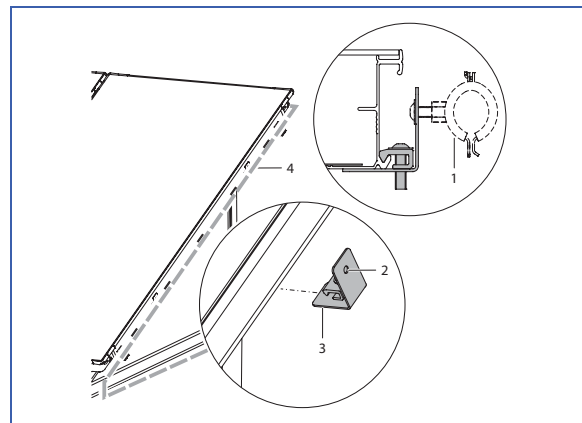


Figure 95 Collector supply line routing

Flat roof support weights

To determine the roof loads, the following weights for flat roof installation kits, use the:

- Standard kit, vertical: 27 lbs
- Standard kit, horizontal: 19 lbs
- Extension kit, vertical: 16 lbs
- Extension kit, horizontal: 19 lbs

Flat roof support fixing (collector stabilization)

Below table is for reference only. Required support varies from site to site and should be verified by a professional engineering firm.

Building height ft	Wind velocity mph	Base anchoring Number and type of screws ¹⁾	Ballast Weight (e.g. concrete bricks) lbs	Guy rope	
				Protection against tilting Weight (e.g. concrete bricks) lbs	Protection against slippage Max. tensile strength per rope lbf
0-25	60	2x M8/8.8	595	400	360
25-65	80	2x M8/8.8	990	700	560
65-300	90	3x M8/8.8	2)	990	740

Figure 96 Options for securing flat roof supports for each collector to prevent tilting or sliding from wind.

- 1) Per collector support
2) Not permitted

Flat roof installation; component selection aid

Consider appropriate attachment materials in the design based on the number of collectors and their hydraulic connections.

		2		3		4		5		
Total number of collectors		2		3		4		5		
Number of rows		1	2	1	2	3	1	2	1	2
Number of collectors per row		2	1	3	2	1	4	2	5	3
				1						2
Installation kits with ballast tray ¹⁾										
FKC-1 and FKB-1 vertical	Standard kit	1	2	1	2	3	1	2	1	2
	Extension kit	1	-	2	1	-	3	2	4	3
	Additional support ²⁾	-	-	-	-	-	1	-	1	-
	Standard kit addition ³⁾	1	2	1	2	3	1	2	1	2
	Addition to extension kit ³⁾	1	-	2	1	-	3	2	4	3
FKC-1 horizontal	Standard kit	1	2	1	2	3	1	2	1	2
	Extension kit	1	-	2	1	-	3	2	4	3
	Standard kit addition ³⁾	1	2	1	2	3	1	2	1	2
	Addition to extension kit ³⁾	1	-	2	1	-	3	2	4	3
Installation kits for on-site attachment										
FKC-1 and FKB-1 vertical	Standard kit	1	2	1	2	3	1	2	1	2
	Extension kit	1	-	2	1	-	3	2	4	3
	Standard kit addition ³⁾	1	2	1	2	3	1	2	1	2
	Addition to extension kit ³⁾	1	-	2	1	-	3	2	4	3
FKC-1 horizontal	Standard kit	1	2	1	2	3	1	2	1	2
	Extension kit	1	-	2	1	-	3	2	4	3
	Standard kit addition ³⁾	1	2	1	2	3	1	2	1	2
	Addition to extension kit ³⁾	1	-	2	1	-	3	2	4	3

Figure 97 Fixing materials for flat roof installation system

- 1) The standard installation and extension kits contain one set of ballast troughs each
2) Not required if the additional extension kit is selected
3) Required in addition to the standard and extension kit with snow loads in excess of 42 lbs/ft² or building height exceeding 65ft

6.3.4 Wall installation

Wall installation is only suitable for horizontal Bosch FKC-1 flat plate collectors, and only for walls up to an installation height of 65 ft.

Wall mounting requires horizontal flat roof supports. The first collector in the row is installed using a wall support standard kit. Every additional collector in the same row is installed using a wall support extension kit. These kits include three supports (Figure 99). The pitch of the collectors on the wall may only be set to between 45° and 60° relative to the horizontal (Figure 98).

On-site attachment

Secure the collector supports on site to structural elements of a wall capable of bearing the load of the collector array in addition to possible snow and wind loads using a minimum of three bolts per support (Figure 99).

Static requirements

The values in Figure 73 are the permissible standard snow loads and building heights.

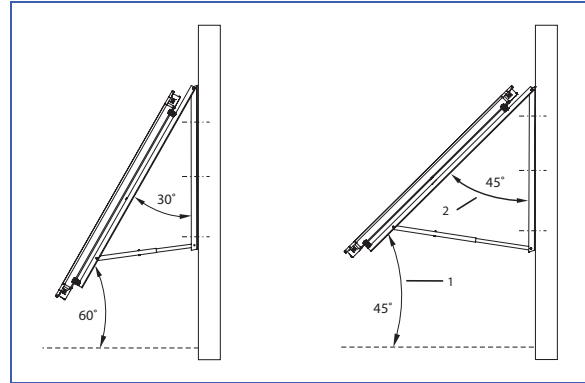


Figure 98 Max. permitted collector pitch on a wall

1: pitch (absolute angle relative to the horizontal)
2: collector angle of inclination

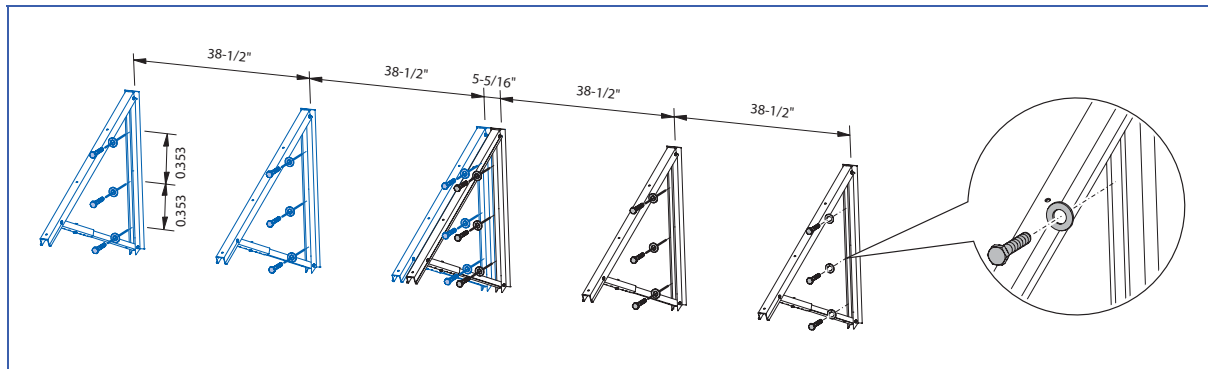


Figure 99 Wall mounting with wall support standard kit and wall support extension kit (blue); dimensions in inches

Snow and ice accumulating on the collectors may give way and slide off suddenly. Take provisions that the installation does not pose a risk to property and cause personal injury from falling snow and ice.

Component selection aid for wall mounting system for Bosch FKC-1 horizontal

	Total number of collectors	2		3			4		5	
	Number of rows	1	2	1	2	3	1	2	1	2
	Number of collectors per row	2	1	3	2	1	4	2	5	3
Installation kits										
FKC-1-w	Standard kit for wall mounting	1	2	1	2	3	1	2	1	2
	Extension kit for wall mounting	1	-	2	1	-	3	2	4	3

Figure 100 Fixing materials for wall mounting system for Bosch FKC-1 horizontal

6.4 Lightning protection and grounding of solar systems

Requirements for lightning protection

Follow the national and local building codes on the installation on lightning arrestors. In the absence of such regulations for the building in question, it is the building owner's responsibility to decide after consulting with professionals if a lightning protection system should be installed.

Take into account that the collector array may be adding height to the building, and that the metal rails may increase the likelihood of a lightning strike.

Lightning protection is typically required for buildings that

- measure more than 65 ft in height
- are significantly higher than the surrounding buildings or horizontal

In buildings open to the public (schools, government, office buildings, etc.) the lightning protection requirements should be discussed with an expert and/or the building operator. This discussion should take place in the planning phase of the solar system.

In residential installations solar systems are typically not significantly higher than the roof itself, and the probability of a direct lightning strike does not significantly increase from the addition of a solar thermal system.

Grounding of the solar system

Irrespectively of whether a lightning protection system is present, the supply and return of a solar system must always be grounded with a copper cable (minimum AWG 9) to the building's grounding rod.

If a lightning protection system is present, determine whether the collector array and the piping are protected by this system. If in question, consult a specialist electrical contractor.

7 Solar applications

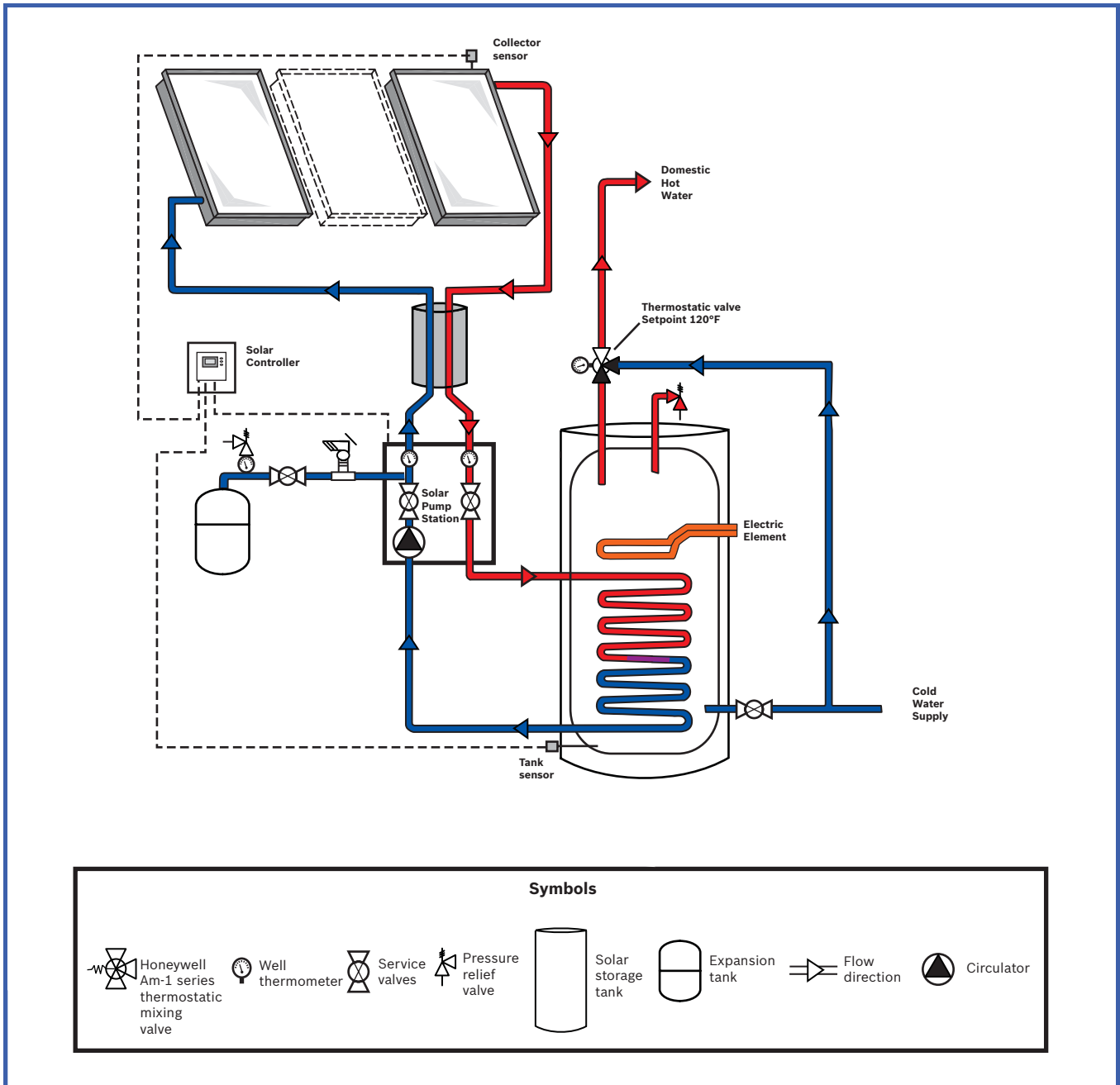
The following drawings are conceptual in nature and may not necessarily display all design, installation, and design considerations. Additional safety and/or auxiliary equipment may be needed or required by code. These drawings are for reference only for officials, system designers, and licensed installers. It is expected that installers and system designers have adequate knowledge of industry practice for the equipment, procedures and applications. The following drawings are not to scale.

- 7.1 Solar DHW system with electric backup element_____pg. 60
- 7.2 Solar DHW system with gas tankless tankloading_____pg. 61
- 7.3 Solar DHW system with gas tankless in line booster_____pg. 62
- 7.4 Solar DHW system with gas tankless in line booster and recirc loop_____pg. 63
- 7.5 Solar DHW system and swimming pool application with gas tankless in line booster__pg. 64
- 7.6 Solar commercial hot water system with gas tankless tankloading_____pg. 65

7.1 Solar DHW system with electric backup element

Electric element keeps comfort zone at top of the tank at temperature. Requires 240VAC single phase.

System can be combined with third party solar PV system for generation of electricity used for electric element, pumps, and other loads.



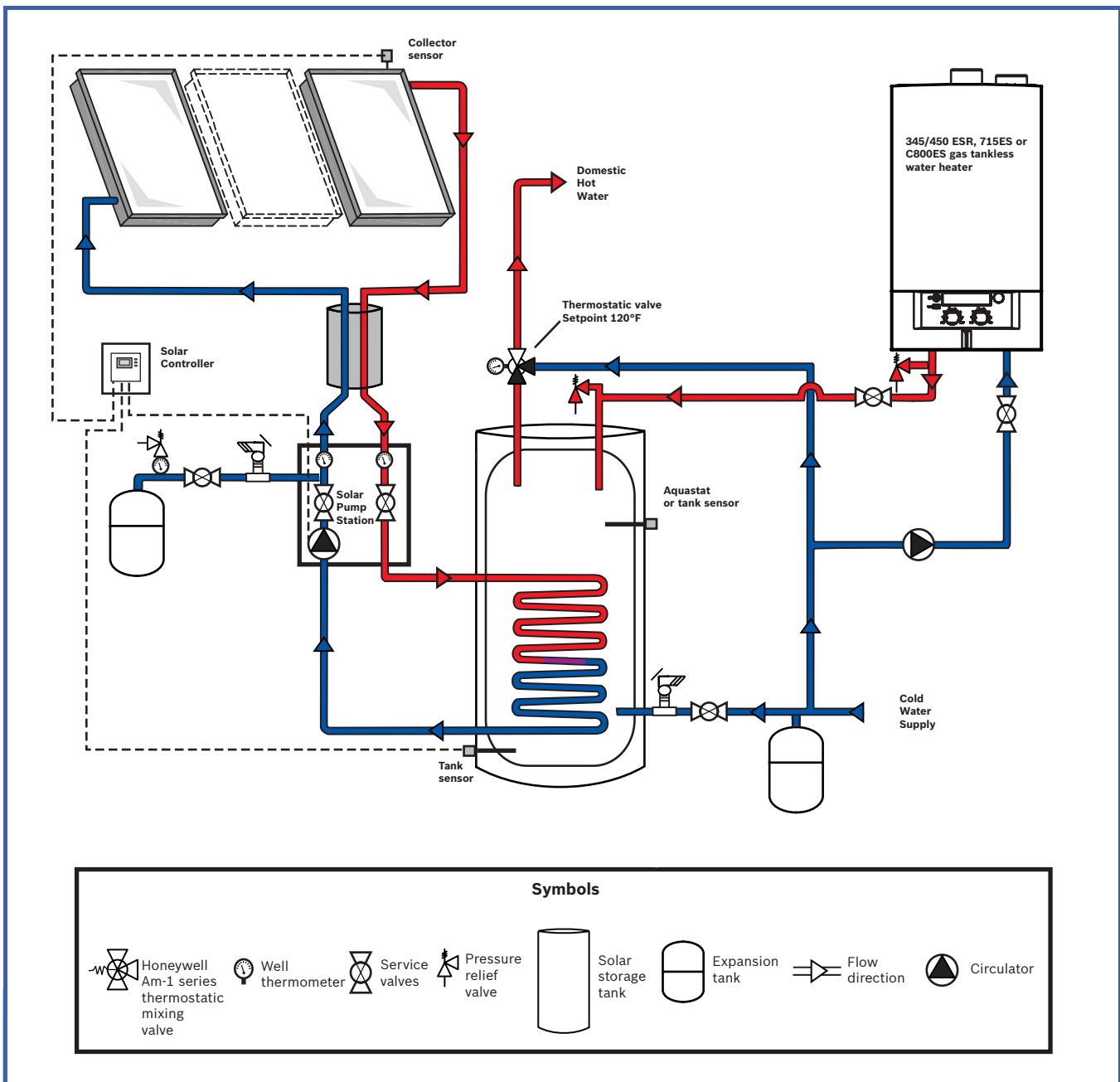
7.2 Solar DHW system with gas tankless tankloading

Tankless water heater keeps comfort zone at top of tank at temperature.

Use flow-activated Bosch GWH715ES or Bosch GWHC800ES with aquastat that activates the circulator. Bosch GWH345ESR or GWH450ESR requires optional 12kOhm tank sensor, and the circulator wires directly to the water heater. See appliance manual for details and wiring diagram. Use of a timer is recommended to interrupt reheating during night time.

Aquastat / Water Heater setpoints		
Model Number	Aquastat setpoint	Water heater setpoint
GWH C 920 ESC	≤140°F	14°F above Aquastat setpoint
GWH C 920 ES	≤126°F*	140°F
GWH 715 ES	≤126°F*	140°F
GWH C 800 ES	≤126°F*	140°F

* If local codes require higher setpoint or to increase the recovery capacity of the water heater, contact Bosch Thermotechnology.



7.3 Solar DHW system with gas tankless in line booster

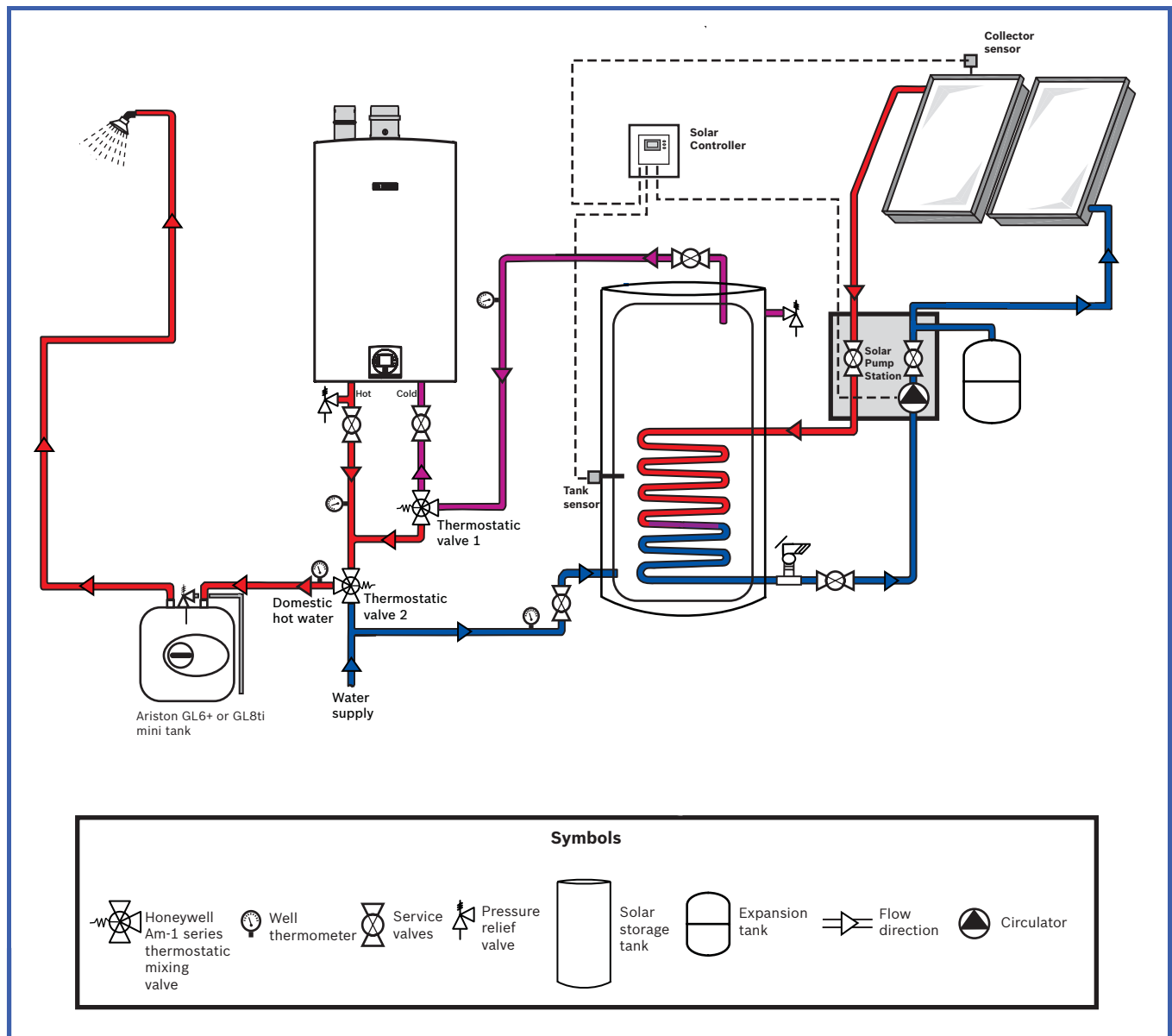
The tankless water heater only runs when solar water needs a boost. Buffer tank provides small amounts of DHW instantly and increases comfort by smoothing out DHW temperature. Recommended appliances: Bosch GWH715 or GWHC800.

Thermostatic valve 1 ensures that warm solar water bypasses the water heater and directs cooler water through the appliance when reheating is needed.

Thermostatic valve 2 acts as a tempering valve that brings potentially hot water temperatures down to a level that is safe for the inhabitants.

System parameters:

- Honeywell AM101 Thermostatic Valves required for proper operation;
- Remove check valves from Thermostatic Valve 1 as it is used as a diverter valve;
- Thermostatic Valve 2 is a tempering valve;
- Recommended setpoint 120°F for both Valves;
- Set tankless water heater temperature to 140° F
- Ariston mini tank will provide increased temperature stability and quicker hot water delivery. (recommended but not required)



7.4 Solar DHW system with gas tankless in line booster and recirc loop

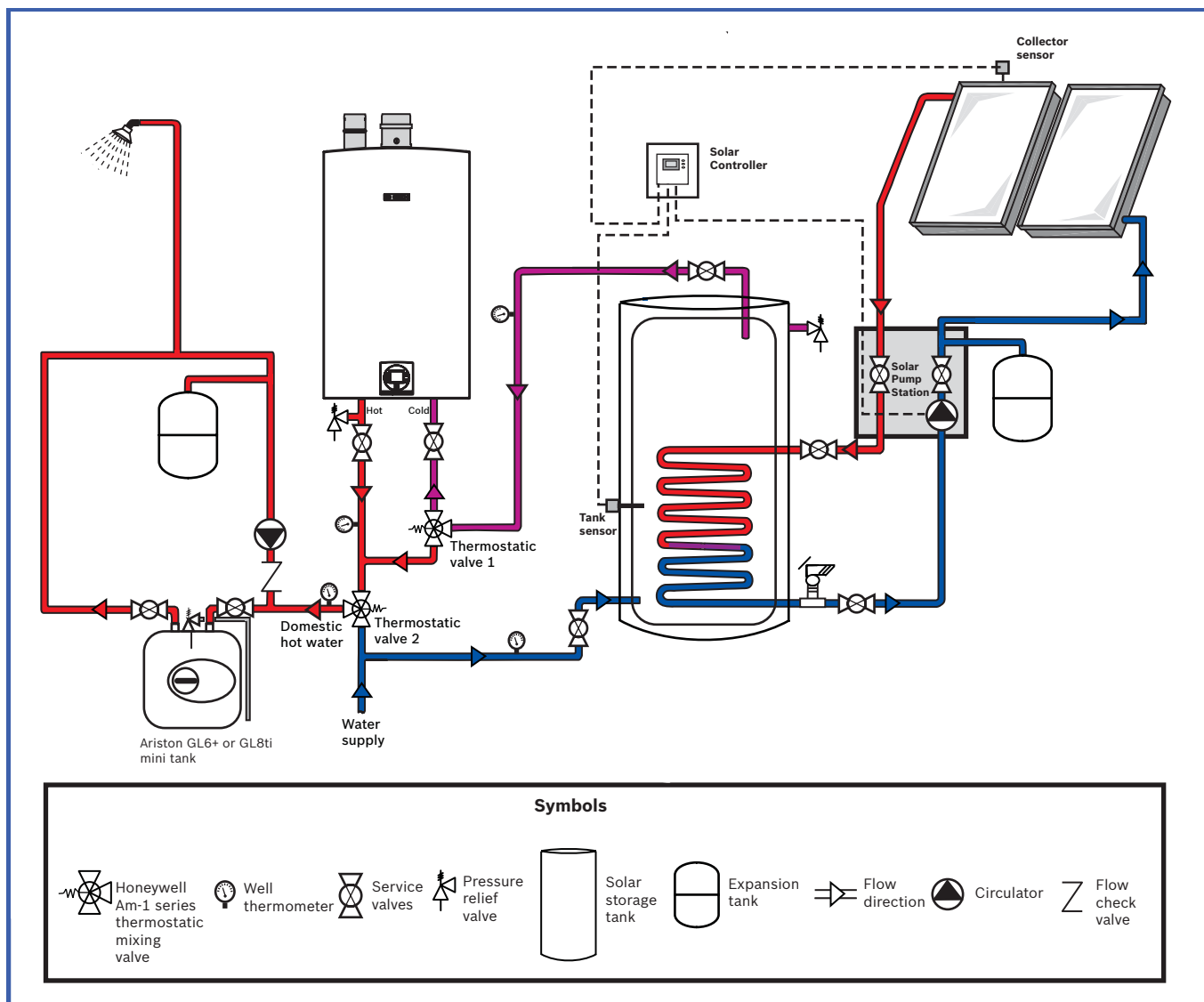
Identical to system 7.4, but with domestic recirculation added. The tankless water heater only runs when solar water needs a boost. Buffer tank provides small amounts of DHW instantly and increases comfort by smoothing out DHW temperature. Recommended appliances: Bosch GWH715 or GWHC800.

Thermostatic valve 1 ensures that warm solar water bypasses the water heater and directs cooler water through the appliance when reheating is needed.

Thermostatic valve 2 acts as a tempering valve that brings potentially hot water temperatures down to a level that is safe for the inhabitants. Do not run the recirculation pump continuously, as it would drain the solar tank. Instead it is recommended to use a timer for the recirculation pump at 3 to 6 runs per hour. Each run must be long enough for hot water to reach the farthest tap. The timer should also limit recirculation pump operation to the time of day when occupants are home and likely to use hot water.

System parameters:

- Honeywell AM101 Thermostatic Valves required for proper operation;
- Remove check valves from Thermostatic Valve 1 as it is used as a diverter valve;
- Thermostatic Valve 2 is a tempering valve;
- Recommended setpoint 120°F for both Valves;
- Set tankless water heater temperature to 140° F
- Ariston mini tank will provide increased temperature stability and quicker hot water delivery. (recommended but not required)
- Choose size of the Ariston mini tank to match the volume of the recirculation loop



7.5 Solar DHW system and swimming pool application with gas tankless in line booster

The tankless water heater only runs when solar water needs a boost. Buffer tank provides small amounts of DHW instantly and increases comfort by smoothing out DHW temperature. Recommended appliances: Bosch GWH715 or GWHC800.

Thermostatic valve 1 ensures that warm solar water bypasses the water heater and directs cooler water through the appliance when reheating is needed.

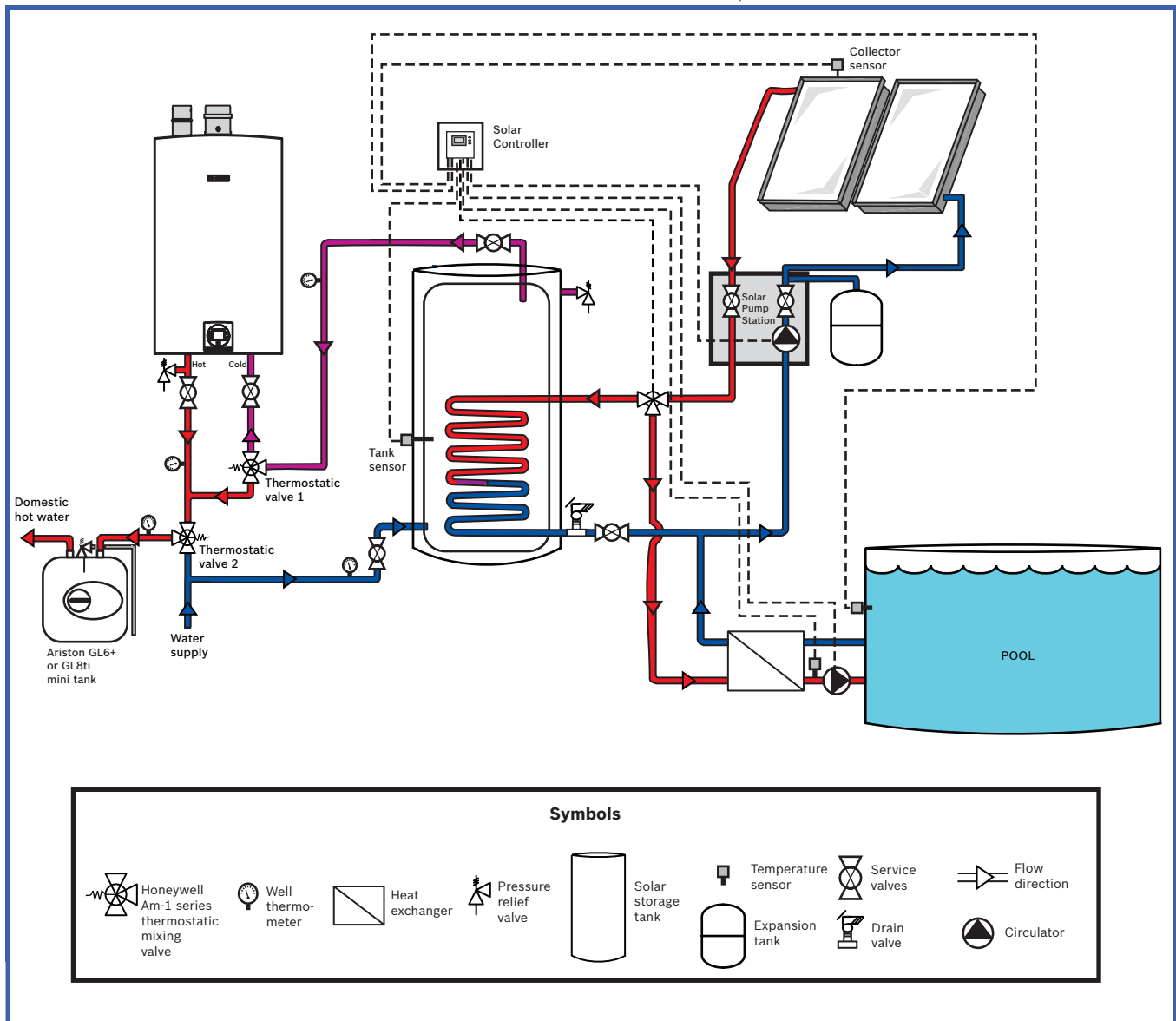
Thermostatic valve 2 acts as a tempering valve that brings potentially hot water temperatures down to a level that is safe for the inhabitants.

Once the DHW target temperature is met, the diverter valve is activated opening the port to the pool heating exchanger.

The swimming pool pump is switched on as soon as the switch-on temperature difference between the external heat exchanger and the swimming pool is reached. When the switch-off temperature difference between the external heat exchanger and the swimming pool is reached, the swimming pool pump switches off.

System parameters:

- Honeywell AM101 Thermostatic Valves required for proper operation;
- Remove check valves from Thermostatic Valve 1 as it is used as a diverter valve;
- Thermostatic Valve 2 is a tempering valve;
- Recommended setpoint 120°F for both Valves;
- Set tankless water heater temperature to 140° F
- Ariston mini tank will provide increased temperature stability and quicker hot water delivery. (recommended but not required)
- 3 port diverter valve with 120V actuator

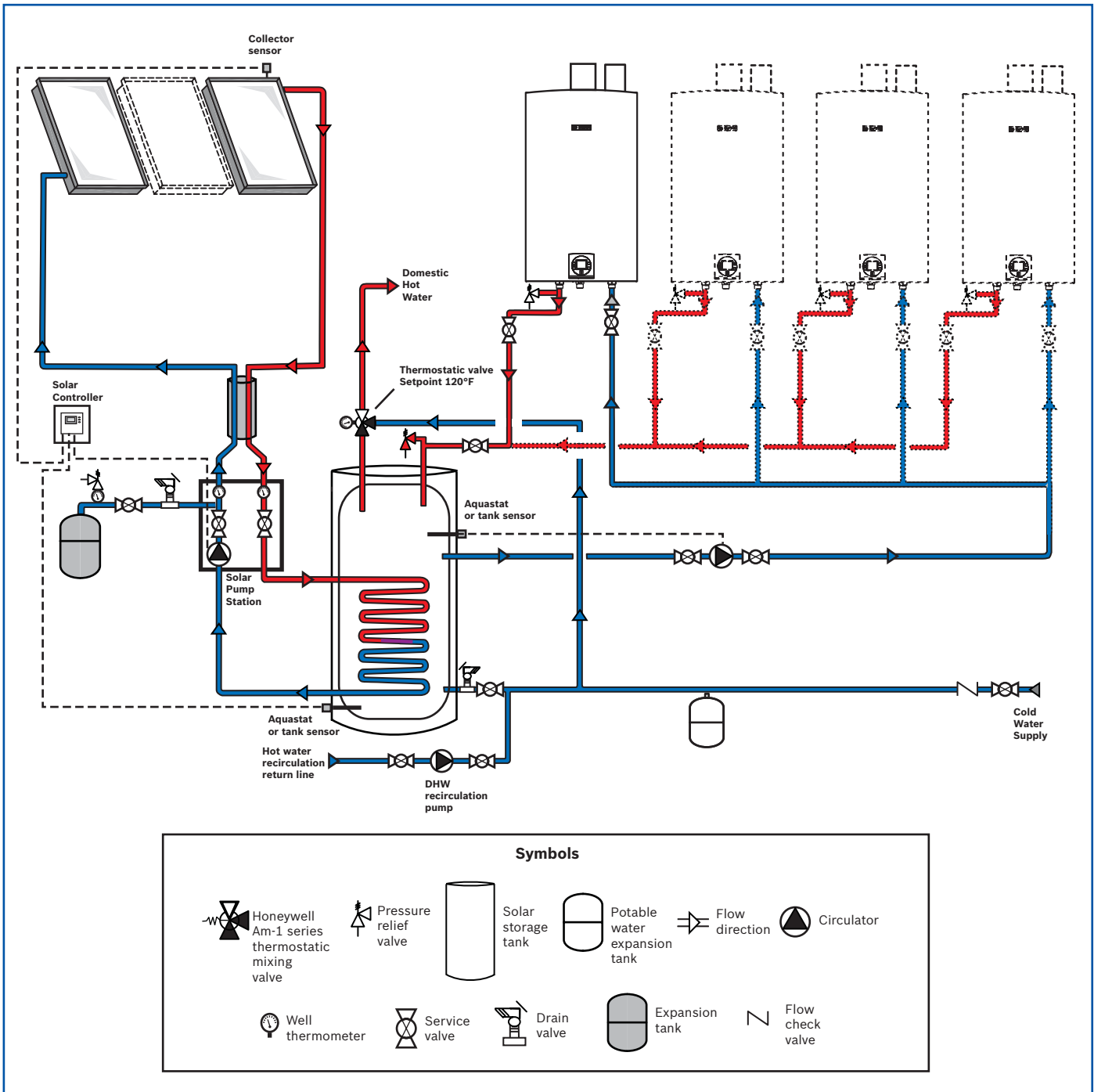


7.6 Solar commercial hot water system with gas tankless tankloading

The following provides a general overview of commercial hot water systems in conjunction with solar water heating. The tankless water heaters keep the comfort zone at top of tank at temperature.

Honeywell AM101 Thermostatic Valves required for proper operation. For optimal performance, the flow through the tankless water heaters should be between 3.5-5 gpm.

Use flow-activated Bosch GWH715ES or Bosch GWHC800ES with aquastat that activates the circulator.



8 System design recommendations

Listed below are important design recommendations to ensure proper operation of the entire solar thermal system.

1. Mount collectors on a roof or wall surface that has sufficient solar exposure.

Ensure at least 6 hours of direct unobstructed solar exposure per day.

2. Avoid mounting collectors where trees, adjacent buildings, or building features (chimneys, etc.) put a partial shade on the collectors.

3. Insufficient insulation of solar pipes lead to excessive losses.

Use proper insulation on all pipes between the collectors and the tank.

4. On the roof ensure all insulation material is resistant to UV rays and weather related wear and tear, as well as does not attract birds or rodents.

5. Do not oversize the collector array in relation to the storage tank volume.

6. Check the system at least once a year for fluid and pressure losses. Find and immediately mitigate any issues.

7. After commissioning, make sure the upper air vent is and remains closed. It only needs checking for accumulated air during the annual system inspection or if system performance indicates air may be in the system

8. Excessive flow rates don't allow the collectors to reach significant temperatures and the delta T between supply and return are small. Refer to chapter 5.4.2 Flow rate in the collector array for the correct flow rate calculation.

9. DEV pressure setting:
Refer to chapter 5.5.2 Diaphragm expansion vessel for details on how to determine the correct DEV pressure setting.

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