Commercial Solar Sizing & Installation Guidelines

Considerations when installing a Solar Thermal System

Energy to the Power of

Kingspan® SOLAR

IMPORTANT

This document is for guidance only. All solar systems should be fully designed by a competent engineer.

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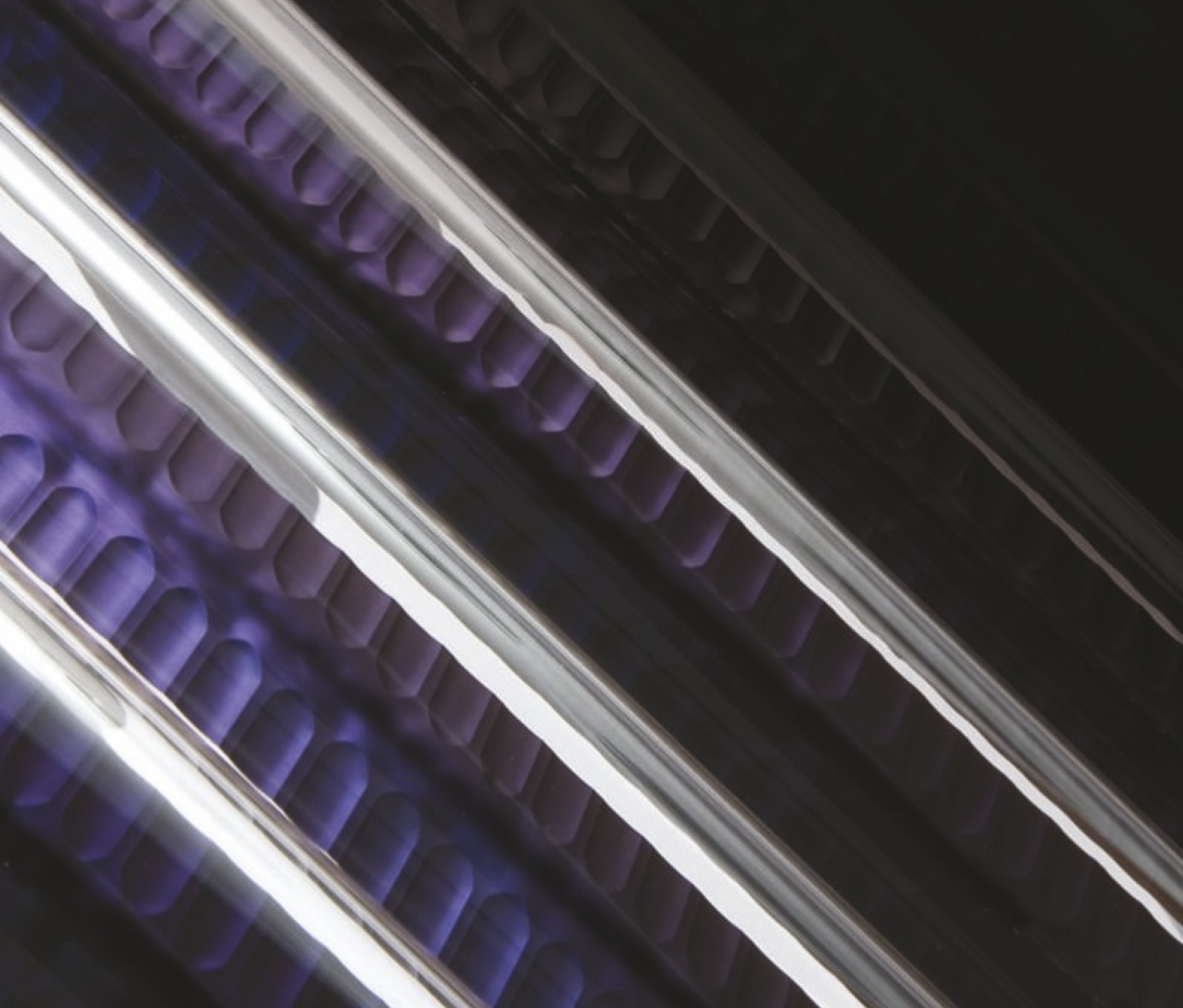

Why Choose Kingspan Solar?

With over 30 years of experience, the Thermomax brand is firmly established as a world leader in solar thermal technology. Kingspan Solar offer quality, market-leading complete packages for all your solar requirements. Each package is custom designed for each specific application. Our premium quality solar panels and hot water storage cylinders are sized and specified to meet the requirements of each individual project. A number of accessories are also available to enhance the system.

Throughout this guide various suggestions have been made for system design and installation. You are strongly advised to follow these suggestions, however, final design of any installation is left to the discretion of the installer.

Regulations and Standards

The solar water heating system should be installed in compliance with current building regulations, all local standards and Health & Safety regulations. These regulations are statutory documents and take priority over all recommendations within this document.

For installation and operating procedures, please refer to the Installation and Operating manuals provided with the products.

International Forum Design Award for Excellence in Product Design

Thermomax products were the first to receive the European quality mark for solar collectors - The Solar Keymark.

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Collectors Installation.

Maximum collector array size:

150 Thermomax tubes (DF100, HP200, HP250, Varisol)

8 no. Flat Plates (CLS1808, CLS2108, CLS2510)
8 no. Flat Plates (FP200V, FP240V)
5 no. Flat Plates (FP200H)
4 no. Flat Plates (FP240H)

Mounting.

A wide variety of mounting kits is available to suit almost any installation. Where collectors are arranged in banks or laid flat, sufficient space of approximately 500mm should be left between each bank to allow for servicing. Due to the wind turbulence around the edges of the roof, we recommend that approximately 1 metre should be allowed between the collectors and the edge of the roof.

Collectors should NOT be left exposed for long periods before commissioning. Long exposure to the sun when fluid is not being circulated through the system will cause significant degradation of the fluid and possible damage to solar collectors. Collectors should only be installed when the required plant, cylinders, pipework and controls etc have been installed and tested.

Where collectors need to be installed for more than a few days before the system is commissioned, collector covers are available to prevent exposure. It is also possible to rotate the tubes in Thermomax panels (DF range only) to prevent the selective absorber coating (blue side) being exposed to the sun. However, although this will minimise the solar irradiation falling on the absorbers, it is only recommended for short periods.

⚠ DF100 and Varisol DF collector tubes cannot be rotated when there is pressure in the hydraulic system. Tubes must be correctly orientated before the system is pressurised.

The Solar Circuit

Pipework.

Pipework for the collector array should be sized based on the following conditions:

For Thermomax tube systems. Solar loop volume flow rate: **60 l/hr/m^2 $\leq$ 12m^2** collector area & **40 l/hr/m^2 >12m^2** collector area.

For flat panel systems. Solar loop volume flow rate: 60 l/hr/m^2 $\leq$ 12m^2 collector area & 40 l/hr/m^2 >12m^2 collector area. For low flow systems: 25 l/hr/m^2 (flat panel only)

Please note, Thermomax tube systems cannot be used with low flow designs.

The maximum flow velocity in the pipework should not exceed 1.0 m/s.
The pipework for the solar circuit must be fully insulated. The thickness of the insulation should be greater than or equal to the internal pipe diameter.

Hydraulic Balancing.

On collector arrays with multiple banks of panels it is important that the correct flow rate is achieved on each bank of collectors. Incorrect flow rates, in particular low flow rates on individual banks can reduce the overall efficiency of the system. In extreme cases the individual bank may stagnate and this could result in damage to the collectors and other system components.

The two methods to best achieve the correct hydraulic balance are high temperature balancing valves or a reverse-return (Tichelmann) pipe arrangement:

1. Individual solar rated balancing valves (flowsetters) on each bank are the preferred method of achieving the correct flow rates. Where the collector banks contain varying numbers of panels or differently sized panels this is the only method of achieving the correct flow rates.
2. Where each of the collector banks are identical in construction a reverse-return (Tichelmann) pipe arrangement may be used.

⚠ Care must be taken to ensure the same fittings and components are used on each bank connection. In this way the pressure loss across each branch will be the same.

Pipe materials.

Suitable pipe materials for solar thermal systems are smooth bore copper, black mild steel or stainless steel. Under no circumstances should plastic or PEX pipe be used. Corrugated stainless steel may be used however, the high pressure loss per length of pipe for this material means it will be unsuitable for all but the smallest systems.

⚠ Galvanised pipe must not be used as it reacts with glycol based heat transfer fluids making them ineffective for frost protection.

Thermal Expansion.

The coefficient of linear expansion of copper is 16.8 x 10^{-6} per °C . In large solar systems the pipe work connecting the collectors may be subject to extreme changes in temperature from subzero in winter to over 170°C in the event of stagnation. Therefore a 10 metre length of copper tube, irrespective of its size, wall thickness or temper, could change in length by up to 33.6 mm (in the temperature range of -25°C to 175°C).

Pipes installed on solar thermal systems must be free to accommodate this expansion, otherwise stresses will build up in the pipework, which may lead to joints being pulled apart and/or tubes fracturing. The magnitude and frequency of such changes in length can result in the reduced life of the joint or failure of the pipe within a short period.

Large loops, horseshoes or changes of direction in the pipework are commonly employed to compensate for thermal expansion. If bellows or gland type joints are used they must be rated for the high temperatures experienced in solar thermal systems.

Frost Protection

Anti-Freeze Protection & Bypass.

In areas prone to sub-zero temperatures for part of the year, care must be taken prevent the heat transfer fluid from freezing and causing damage inside the collector, external pipework or heat exchanger. In these areas a mixture of water and antifreeze (conventionally propylene glycol) is used.

To prevent errors in the % concentration of glycol, Kingspan offer premixed solutions of glycol with 25% and 45% concentration, depending on region.

1.2-propylene glycol is a non-flammable liquid that is non-toxic and biologically degradable. Subject to EU criteria it is neither subject to compulsory marking nor to special transport regulations.

Where freezing protection is not required, Kingspan can provide a special formulation of corrosion inhibitors which is compatible with evacuated tube solar collectors.

Bypass Loop

A bypass valve and the controller ‘Bypass function’ should be activated for systems with pipe runs greater than 20m (one way) or where over 50% of the pipework is outside the building. The purpose is to preheat the solar loop before introducing the heat to the heat exchanger. This prevents cooling of the storage and the risk of frost to the heat exchanger.

⚠ For the Bypass function to operate effectively a suitably sized 3 port diverter valve & additional controller sensor (PT1000) must be ordered. The sensor should be installed on the solar flow side of the diverter valve.

Stagnation Prevention

Heat Dissipation.

A heat dissipater is required for all Thermomax direct flow collectors.

Any heat pipe collector system with long periods of reduced consumption or a seasonal demand eg a school, university, holiday home etc. will also require a heat dissipater.

Sizing guide for heat dissipater (based on ΔT = 40°C with no forced circulation):

- 420 W/m2 collector area for evacuated tube collectors
- 250 W/m2 for flat plate collectors

The Kingspan 'Heat Dissipater' (code KSP0237) is suitable for up to **40 tubes**.

Steam reach.

During stagnation the heat transfer fluid in the collectors may vaporise. The vapour will expand into the connecting pipe work. In large systems with direct flow collectors, the volume of heat transfer fluid in the collector will be large and the vapour may travel a significant distance along the connecting pipework.

Where sensitive components such as pumps, valves and expansion vessels may be affected by the high temperature vapour, a steam reach calculation should be performed to assess the areas of the system that could be affected. An example calculation is given in **Appendix 1**.

Pump Stations and Safety Components

Pumping stations.

A range of solar pumping stations are available for all sizes of solar thermal systems. The selection of the pump station depends on the size of the collector array, the required flow rate and the overall pressure loss in the system. An example pump sizing calculation is provided in **Appendix 2**.

Pump station KSP0106 requires a flow meter to be installed separately in the return pipe below the pump station.

Pump stations KSP0156 & KSP0157 require a flush & fill point to be installed separately in the return pipe below the pump station.

Expansion & Cooling Vessels.

In closed loop systems a suitable sized expansion vessel must be fitted to maintain pressure in the system as the fluid expands and contracts during normal operation. The expansion vessel must be sized to allow for vaporisation of the heat transfer fluid in the event of stagnation. The expansion vessel pressure should be preset to 15% lower than the calculated system pressure to enable it to function correctly.

Where an expansion vessel could be affected by high temperature vapour during stagnation a suitably sized cooling vessel should be placed in series before the expansion vessel to provide protection to the expansion vessel membrane.

⚠ A direct flow system will almost always require a cooling vessel.

Air & venting.

On large solar thermal systems with multiple banks of collectors, it is often impractical to fit air vents to each collector bank. If automatic air vents are fitted to a glycol filled system these must able to be isolated with a valve to prevent venting of glycol vapour during stagnation events.

⚠ Air vents should be manually operated only, automatic vents may be used during commissioning only and then isolated.

The recommended solution to remove air from the system is to fit a deaerator or vacuum degasser to the system. On large systems fitted with heat exchangers it is important to prevent dirt entering the heat exchanger that could potentially block the flow channels and reduce the heat transfer efficiency. A combined deaerator and particle filter is therefore recommended for these systems.

Safety Valves.

A suitable safety pressure relief valve must be installed in the solar circuit. The safety valve must be appropriately sized for the heat output of the collector array and must be able to transfer their maximum output (optical output η_0 @ 1000 W/m^2) in accordance with EN 12976 and 12977. Use only safety valves rated for maximum 6 bar and 120°C, which bear the marking "S" (solar) as part of the product identification. These safety valves cannot be mounted at the heat source (the collector). Instead they must be installed in the solar thermal system return pipe in a flow direction downstream of the check valve. Ensure that at this point, no temperatures > 120°C can occur.

Solar Loading Module and Fresh Water Modules

Unit Sizing:

Solar Loading Modules (SLM):

The Kingspan range of Solar Loading Modules is designed to enable the efficient production of large volumes of hygienic hot water from thermal stores and assist with the stratification of hot water in large volume storage.

Sizing guide: sized on total collector flow rate (l/min) for primary side
e.g. SL75 = maximum flow rate 75 L/min.

Fresh Water Modules (FWM):

The Kingspan range of Fresh Water Modules is designed to enable the efficient production of large volumes of hygienic hot water from thermal stores to point of use.

The size of these units is based on the system peak tapping flow rate for secondary side of FWM
e.g. FWM 150 = maximum hot water tapping flow rate 150 L/min @ ΔT = 50°C.

Storage sizing for SLM & FWM units:

Large/commercial system sizing guide: allow 55 litres of sanitary water storage per m^2 of collector area.

Preheat Reheat system:

- preheat tank (store half the daily demand)
- reheat tank (store half the daily demand)

SLM / FWM Instantaneous System:

- buffer tanks = store twice (x2) the daily hot water demand

SLM / FWM Semi-Instantaneous System:

- buffer tanks = equal to daily demand
- reheat tank = equal to daily demand
- buffer tanks = 35 litres per m^2 collector area (minimum)

Rule: The solar coil surface area must be at least 0.2 – 0.3 m^2 per m^2 collector aperture area (Source: VDI 6002 Part 1).

Control system.

Temperature measurement.

Control of a solar thermal system is usually based on temperature differentials. Therefore it is important that attention is given to the location and connection of temperature sensors to ensure accurate readings.

On large collector arrays with multiple banks where one collector temperature sensor is used for control the sensor should be located as follows:

The accuracy of PT1000 temperature sensors decreases with long cable lengths. The cable length should be kept to a minimum by locating the sensor on the closest un-shaded collector bank to the controller. Ensure the correct extension cable is used (0.75mm^2 cross-section for up to 50m or 1.5mm^2 cross-section for up to 100m). Any exposed connections must be weatherproof. Ideally a junction box providing lightning protection should be used (KEK0017).

Sensors for tanks or heat exchangers must be inserted into a sensor pocket to ensure accurate measurement of the liquid temperature. Ensure sensors are firmly held in the pocket and that they cannot be easily pulled out if the cable is accidentally pulled.

When pipe sensors are clamped to the pipe, the pipe must be clean to ensure a good thermal contact. Clamp the sensor to the pipe using a method suitable to withstand the maximum possible temperature at the location.

Alarm connections are available (Volt free contacts) on all controllers to enable alarm indication on a Building Management System (BMS).

Commissioning.

Flushing & Filling.

Solar thermal systems should only be filled when the system is cool. This means they must be filled in the morning before they become heated by the sun, in the evening when they have cooled, by covering the collectors to block the solar radiation or on an overcast day when there is minimal solar radiation.

An exception to this is the HP range of tube collectors, HP200, HP250, HP400 & HP450. With these collectors the manifolds may be installed without the tubes in place. In this case no solar energy is collected so the pipework will remain cool. This allows the hydraulic system to be commissioned at any time without concern of overheating the heat transfer fluid.

⚠ Systems which are to operate with a glycol mixture as protection against frost must NOT be tested for leaks by using water. Instead, air should be used when pressure testing these circuits.

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Appendix 1 - Steam Reach Calculation

Example Steam Reach calculation.

The following methodology is based on research by The Fraunhofer Institute for Solar Energy Systems ISE, Institute for Solar Energy Research Hameln/Emmerthal (ISFH) and Solar and Thermal Engineering (SWT) Stuttgart.

A planned solar thermal system is to consist of five 30 tube DF100 panels connected to a 1000ℓ buffer vessel with an internal heat exchanger. The panels are connected in a single bank with the tubes vertical. The pipework consists of 22mm copper with mineral wool insulation. The length of return pipe from the pump station to the collector inlet is 32m. The length of flow pipe from the collector outlet to the pump station is 43m.

The maximum steam reach is calculated using the following formula:

$$L_{s\max} = \frac{P_{s\max} \times A_C}{q_{pipe}}$$

Where L_{max} = maximum steam reach (m)
$P_{s\ max}$ = Maximum steam power factor (W/m²)
A_C = Collector array aperture area (m²)
q_{pipe} = heat dissipation factor for pipework (W/m)

Figure 1 below shows values for the Maximum steam Power factor for Kingspan collectors:

Figure 1

Collector	**Steam Power factor (W/m2)**
FP200V/240V	60
DF100 (tubes horizontal)	50
HP250	100
DF100(tubes vertical)	200

Note: The temperature limitation mechanism employed in the HP200 collectors means that no vaporisation will occur and so there is no steam power factor for this collector.

Figure 2 below shows values for the heat dissipation factor for pipework of various size copper pipes with full insulation.

Figure 2

Pipe dimensions	Heat dissipation factor (W/m)
12 x 0.6	25
15 x 0.7	25
22 x 0.9	30
28 x 0.9	30

For the example system above, the maximum steam reach in metres is calculated as:

$$L_{s\max} = \frac{200 \times 5 \times 3.228}{30} = 107.6m$$

This result shows that steam will penetrate a significant distance into the system. It can be assumed that the steam will penetrate evenly along both the flow and return pipes i.e. a distance of 53.8m each side. This is greater than the 32m length from the pump station to the collector inlet. Therefore, if the expansion vessel is connected to the pump station it will almost certainly be affected by high temperature steam. This could damage the membrane in the expansion vessel.

To protect the expansion vessel membrane in this case a cooling vessel must be fitted in series with the expansion vessel. The size of cooling vessel required can be determined by calculating the difference in length between the penetration length and the actual return pipe length. The required volume of cooling vessel must be greater than the volume of this length of pipe. Therefore:

Difference in length = 53.8 – 32 = 21.8m

Volume of pipe (m^3) = 21.8 x π x $(0.0202)^2$ / 4 = 0.00698 m^3

Therefore the cooling vessel required must have a volume larger than 6.98 ℓ.

⚠ The surface of cooling vessels can become extremely hot. Contact prevention measures may be needed.

Appendix 2 - Pump Sizing Calculation

Example - a planned solar thermal system is to consist of five 30 tube HP200 panels, connected to a 1500 ℓ buffer vessel with an internal heat exchanger.

Step 1: Calculate the required system flow rate.

A 30 tube HP200 panel absorber area = $3m^2$

Total absorber area = 5 x $3m^2$ = $15m^2$

System flow rate @ 40 ℓ/m^2/hr = 15 x 40 ℓ/m^2/hr = 600 litre/hr
Flow rate per minute = 10 ℓ/min

Step 2: Calculate the required pipe diameter.

To maintain a flow velocity of less than 1 m/s at a flow rate of 10 ℓ/min the internal pipe diameter must be greater than:

$$\emptyset i = 4.6\sqrt{\frac{system\ flow\ rate\ (l\ /\ min)}{velocity\ of\ fluid\ (m/s)}}$$

$$\min \emptyset = 4.6\sqrt{\frac{10}{1}} = 14.55mm$$

Therefore if copper pipe is used the solar circuit will require 22mm copper pipe.

Step 3: Calculate the pressure loss in the pipework.

From Table 1 the pressure loss in 22mm copper pipe at 10.8 ℓ/min is 1.90 mbar per meter length. Therefore if the pipework length is 40m (flow and return) then the total pressure loss in the pipework can be calculated as:

ΔP_p = 40 x 1.90 = 76 mbar.

To account for elbows, adapters, valves etc these can be equated to an equivalent length of additional pipe. Table 2 shows values for various fittings.

In this example system, we have 8 minimum radius bends and 4 compression elbow joints. The fitting pressure loss is:

ΔP_f = (8 x 0.41) x 1.9 + (4 x 1.00) x 1.9 = 13.8 mbar

If the pressure drop data is not available, allow at least 20% for pressure drops across bends, valves and pipework.

Step 4: Calculate the pressure loss in the collector array.
The pressure loss across 1 HP200 30 tube panel at 10 ℓ/min is given by:

$\Delta P = 0.917 \times (10)^2 + 0.708 \times 10 = 98.78$ mbar

The pressure loss across the collector array is the sum of the pressure loss across each panel in the array.

$\Delta P_c = 5 \times 98.78 = 493.9$ mbar

Step 5: Calculate the pressure loss in the tank heat exchanger.

The pressure loss for coil heat exchangers is usually found in the manufacturer's data. In this example the coil heat exchanger in the 1500ℓ buffer vessel at 10 ℓ/min flow rate is as follows:

$\Delta P_{hex} = 80$ mbar

Step 6: Calculate the total pressure loss in system.

$\Delta P_{total} = \Delta P_p + \Delta P_f + \Delta P_c + \Delta P_{hex} = 663.7$ mbar

Step 7: Select the correct pump station and pump.
The presence of the pump station will add an additional pressure loss to the system that must also be considered. The pump curves and pressure loss of the KSP0025 and KSP0033 pump stations are shown below. At 10 ℓ/min flow rate both stations have a pressure loss of approximately 2.5 mbar (0.25 kPa).

The total pressure loss in the system would now be 666.2 mbar.

From the pump curves for the KSP0025 the pump head at 10 ℓ/min is approximately 520 mbar. This is lower than the 666.2 mbar that was calculated as being required to overcome the pressure losses in the system. Therefore, the KSP0025 station would not be suitable.

For this system the KSP0033 station should be selected. At the flow of 10 ℓ/min the pump head is approximately 720 mbar. This is sufficiently larger than the required value of 666.2 mbar to allow a reasonable margin for error.

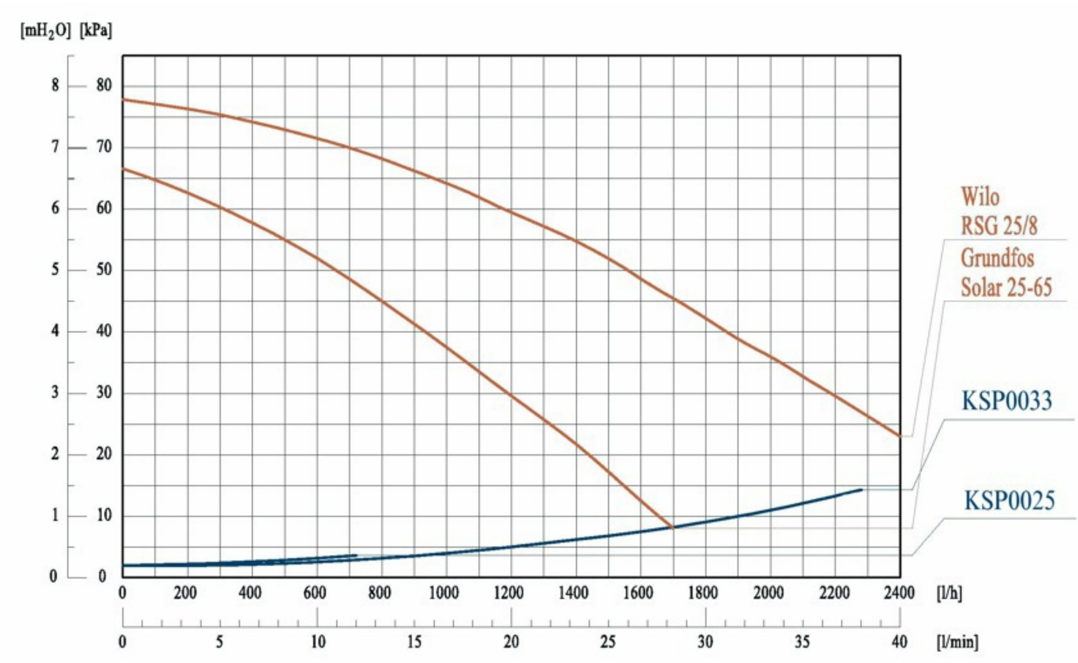
Table 1 - Pipe Pressure Loss Table

Pressure loss & Pipe Diameter for Copper pipe (EN 1057)					
	Pressure loss per meter pipe (mbar/m) (Note: blue text indicates velocity range of 0.4 - 1 m/s)				
Flow rate	Pipe Diameter x Wall Thickness (mm)				
L/min	10 x 0.6	12 x 0.6	15 x 0.7	22 x 0.9	28 x 0.9
1.5	3.2	1.2	0.4	0.1	
1.8	4.4	1.7	0.6	0.1	
2.1	5.8	2	0.7	0.1	
2.4	7.2	2.5	0.9	0.1	
2.7	8.9	3.2	1.1	0.2	0.1
3	10.8	3.9	1.4	0.2	0.1
3.6	14.8	5.5	1.8	0.3	0.1
4.2	19.2	7.2	2.4	0.4	0.1
4.8	24.7	9.2	3	0.5	0.1
5.4		11	3.7	0.6	0.2
6		13.4	4.4	0.7	0.2
7.2		18.3	6.1	0.9	0.3
8.4			8	1.3	0.4
9.6			10.2	1.6	0.5
10.8			12.5	1.9	0.6
12			15.2	2.3	0.7
15				3.4	1
18				4.7	1.4
21				6.2	1.8
24				7.9	2.3
30					3.4
36					4.7
42					6.2

Table 2 - Resistance/Pressure Loss of Fittings

Fitting resistance's as equivalent straight lengths of copper pipe (m)					
Flow rate	Pipe Diameter				
Fitting type	10	12	15	22	28
Straight pattern valve	0.15	0.2	0.3	0.4	0.6
Angle pattern valve	1.5	1.8	2	4.3	6
Minimum radius bend	0.16	0.2	0.26	0.41	0.58
Compression elbow	0.33	0.42	0.6	1	1.3
Square tee	0.37	0.49	1	1.6	2

Table 3 - KSP0025 & KSP0033 Pump Curves



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