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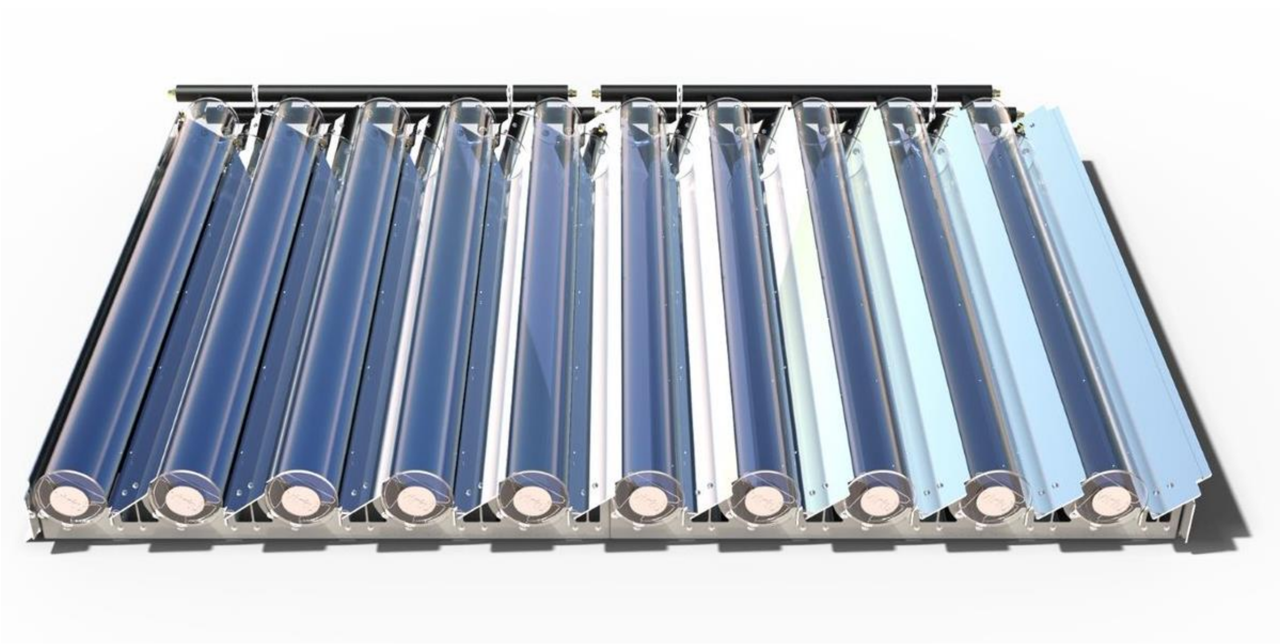
Document	VirtuHOT and VirtuHOT HD Installation Manual
Description	Site Preparation, System Design, Installation, Commissioning and Maintenance Documentation
Revision	October 2024



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Contents

1. **Overview**

VirtuHOT is an evacuated tube solar thermal collector that is designed to mount horizontally. The borosilicate glass tube is approximately 2 meters long and has a diameter of 180 mm. VirtuHOT collectors can be mounted on the ground or on buildings. The geometry is particularly well suited to mounting on a flat roof, since the tubes can be placed horizontally on the roof on their dedicated support frame, without the need for mounting rails or brackets. Unlike solar flat panels that need to be mounted on A-frames to achieve the correct angle to the sun, VirtuHOT can be mounted flat on the roof, with the absorber plate tilted (inside the tube) to face the sun direction. This simplifies the installation process compared to other flat panel solar collectors.

There are 2 versions of the product, called VirtuHOT and VirtuHOT HD. VirtuHOT has a tube spacing pitch of 300 mm and a flat mirror reflector between each tube. VirtuHOT HD has a smaller tube spacing of pitch 220 mm and no reflector. These 2 versions accommodate the different sun angles associated with different locations (latitudes) and mounting orientations (flat roof, sloped roof). VirtuHOT offers the highest thermal output per tube, while VirtuHOT HD offers higher energy density when mounted at high sun angle (e.g. at latitude <20 degrees).

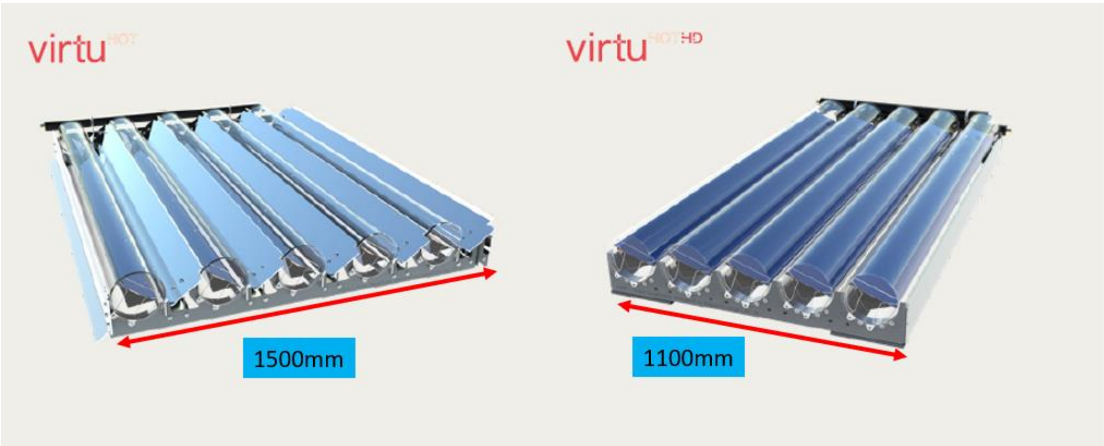


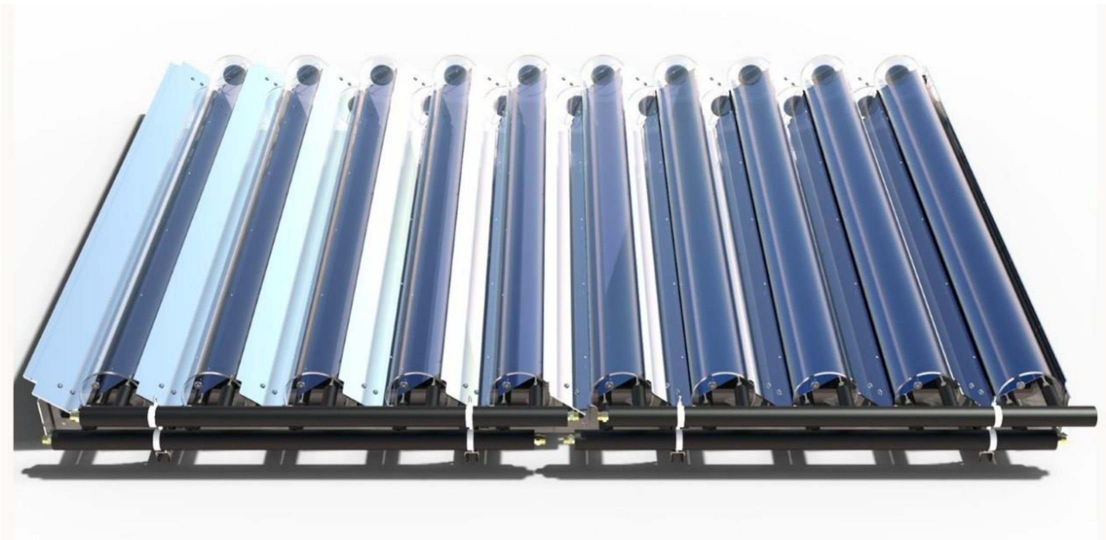
Figure 1 - Side views of VirtuHOT and HD highlighting the difference in width and increased Energy Denisty

This installation document describes the methods for installing VirtuHOT and VirtuHOT HD on flat roofs, inclined roofs and vertical facades. The detailed descriptions and figures refer mostly to VirtuHOT; the methods for VirtuHOT HD are all the same, but without the addition of the reflectors.

The schematic below shows how Virtu collectors are arranged in rows of up to 20. The evacuated tubes are supported on an aluminium frame and the reflectors are attached between each tube.

The water connections from inside each tube connect into two 22 mm diameter manifolds that run alongside each row of tubes in the service corridor. The tubes in each row are plumbed in parallel. Adjacent rows can be connected in series or parallel. There 22mm manifolds once connected to the water connections create the main flow and return circuits and are connected to a pipe circuit which returns to the plant room.

Figure 2 - Bank of 5 VirtuHot on Frames



2. Safety Information

Installation of Naked Energy solar collectors must only be carried out by a qualified contractor, who has relevant experience and expertise in solar thermal equipment and has been trained in the installation methods for Virtu. Please contact Naked Energy to receive the relevant training.

Installation should be carried out in compliance with all local planning requirements, building regulations and codes, health and safety legislation, and any relevant local by-laws and regulations in force at the time.

Access to a VirtuHOT installation should be controlled and personnel with access should be made aware of the risks associated with the VirtuHOT installations, as detailed in this section.

Prior to installation of Virtu collectors, a detailed risk assessment should be completed by the installation site manager, taking account of all steps in the installation and commissioning plan. The risk assessment should be approved by the customer or site controller ahead of time and should form the basis of a safety briefing that will be given to the installation team before work commences. The risk assessment should define all potential risks and identify control measures and PPE (Personal Protective Equipment) that should be worn by the installation team.

⚠WARNING Glass tubes under vacuum and broken glass risk
Virtu collectors have a glass tube under vacuum, which represents a hazard if broken. If a heavy object were dropped on the glass tube or it were dropped during installation, the glass tube could break, possibly resulting in flying glass fragments. This represents a particular risk of serious eye injury and protective glasses should be worn during installation of Virtu tubes.

⚠WARNING Risk of burn from hot pipework
Solar thermal collectors can heat to high temperatures. During normal operation temperatures as high as 80°C can be reached. In a fault mode, when water flow has stopped with high sun intensity (known as a stagnation condition), temperatures up to 150°C can be reached on pipework and 200° C within the collector. These high temperatures can present a burns risk, if for example thermal insulation is removed from the pipework during maintenance and the pipe touched.

WARNING Risk from falling objects
Parts mounted on a roof or wall can present a risk from falling objects. If parts are not correctly secured or could become loose during high winds or as a result of long term weathering, they could fall and cause damage or harm to people or property below, including risk of serious injury or death. It is essential that the solar collectors, reflectors and other parts of the array and system are correctly installed and secured, according to the installation procedures and using approved parts and fittings.

WARNING Risk of falling from height
If installation or maintenance involve working at heights, they should only be carried out by personnel that have been trained or briefed on working at heights. Suitable equipment and protection measures should be put in place, such as barriers, edge exclusion zones or fall restraint systems. Falling from height can present risk of serious injury or death.

WARNING Risk of roof damage or collapse
A structural engineer report should be provided to demonstrate the roof or mounting surface is strong enough to support the weight of the solar array, including consideration of average loading and point loading. Failure to confirm this could result in property damage, serious injury or death.

WARNING Risk from manual handling
During installation or maintenance, there is a risk of injuries due to manual handling, such as knee or back injuries. This is especially the case when installing and connecting collectors at a low level, requiring bending down. Virtu tubes should only be carried by 2 people, one at each end of the tube. Manual handling training or briefing should be given to all personnel carrying out work that includes manual handling, so that they avoid actions and working positions that can increase the risk of injury.

WARNING Release of steam at elevated temperatures
When the Virtu collectors are being heated by the sun, glycol/water circulation should be maintained and heat removed to ensure the collectors do not heat above 100°C (over-heating without fluid flow is known as

stagnation). If a stagnation event is allowed to occur in the solar array, steam can be released at high pressure e.g. from the pressure relief valves (PRVs). PRVs should be connected to a containment vessel or suitable drain, to ensure hot water or steam is safely discharged. If stagnation (no glycol/water flow) in sunny conditions does occur, the collectors should be allowed to cool before circulation of colder fluid (glycol/water) is re-started, to avoid a thermal shock that could damage the collectors. A thermal shock may occur if the collectors are more than 40°C hotter than the circulating fluid. Cooling the collectors can be achieved by waiting until late afternoon or covering the collectors, so that there is no sun on the collectors, and waiting for the temperature to drop. The waiting time will depend on the temperature reached, but may require at least 1 hour. Steam released from the system during stagnation or subsequent thermal shock could result in a risk of burns to personnel near the array.

⚠WARNING Use of chemicals

Certain chemicals are used in solar thermal arrays, including cleaning solutions, glycol (or other anti-freeze solutions) and glass coatings (to reduce soiling). Before using any chemicals it is essential to check the MSDS safety documentation and follow any measures specified, such as wearing PPE (personal protective equipment). A copy of MSDS documentation should be taken to site during installation, in case there is an urgent need to refer to it e.g. in the case of spillage.

⚠WARNING Installation during bad weather

Weather forecasts should be checked prior to installation or maintenance activities. If severe weather is forecast, such as high winds, freezing temperatures or heavy rain or snow, an assessment should be made as to whether the activity can proceed or should be delayed. Severe weather can significantly increase the likelihood of some of the risks detailed in this section, such as the risks from broken glass, falling objects and working at height.

⚠WARNING Legionella

When designing systems for provisions of sanitary/domestic hot water, care should be taken to ensure that the installed solar hot water system does not create a legionella risk, which could be hazardous to the health of the hot water users. Solar pre-heat systems in particular must be designed carefully, since water is stored at temperatures above the mains temperature but often below 60°C, which creates the highest risk of bacteria growth. See section 6.11 for more detail.

WARNING Commissioning Essentials
It is essential to have data communications installed as part of the commissioning process. This is to aid remote monitoring in the first few weeks, until the system is confirmed to be running as designed. Failure to install communications may result in system operation errors not being detected, and may invalidate the product warranty.

WARNING Deviation off Design
Any deviation in product or system design, involving product alteration or use that is outside the guidelines described in this manual, requires approval from Naked Energy Ltd before proceeding. Failure to obtain permission may invalidate the product warranty.

WARNING Design Liability
Naked Energy are neither an installation contractor nor a system designer. Any system related information in this manual is being provided for guidance only and does not imply Design Liability. Any system design for a VirtuHOT installation must be approved and signed off by the Principal Designer for the project.

3. Data Sheet and dimensions

PRODUCT	VirtuHOT	VirtuHOT HD
DIMENSIONS		
Width (pitch)	300 mm	220 mm
Length (tube)	2155 mm	2155 mm
Length (tube and manifold)	2260 mm	2260 mm
Service corridor	250-500 mm	250-500 mm
Height (or depth on façade mount)	265 mm	265 mm
Absorber Area	0.331 m^2	0.331 m^2
Gross Area of Tube	0.647 m^2	0.474 m^2
Total Area on Roof per Tube (with 4 rows)	0.753 m^2	0.552 m^2
Total weight (wet) per Tube	19.3 kg	14.6 kg
Roof loading (with 4 rows of tubes)	25.7 kg/m^2	26.4kg/m^2
Absorber plate inclination	35º	0º (or +/-20º)
MATERIALS		
Absorber Plate	Aluminium with low emissivity coating, copper pipe	
Mounting Frame	Aluminium	
Glass	Borosilicate 3.3	
ENERGY OUTPUT - per tube		
Peak Thermal output [1]	400 W	290 W
OPERATING CONDITIONS - thermal		
Flow Rate Range	0.1-1 l/min	
Maximum Pressure	6 bar	
Water Output Temperature Range	10 – 90°C	
Stagnation Temperature (at 1000 W/m2)	260°C	
Water volume in collector	150 ml	
Manifold diameter (external)	22 mm	
Heat Transfer Fluid	Water / Glycol	

Table 1. Key dimensions, materials and operating parameters of a single VirtuHOT tube.

Notes:

1. Standard Reporting Conditions (1000 W/m2, 20°C ambient, 1.3 m/s wind speed) at optimal incidence angle

Figure 3 – VirtuHOT and VirtuPVT Tubes on a sloped roof

4. Site preparation and layout

The optimum orientation for Virtu is with the tubes along the East-West axis and the absorber plate tilted towards the South. If the shape and orientation of the mounting area is not aligned to the East-West axis, the tubes can be aligned at a different angle (by up to 45 deg rees), but thermal output will be somewhat reduced (10-20%) and shifted in time. For example if the tubes are oriented along a SW-NE axis with the absorbers titled towards SE, then the morning output will be greater than the afternoon.

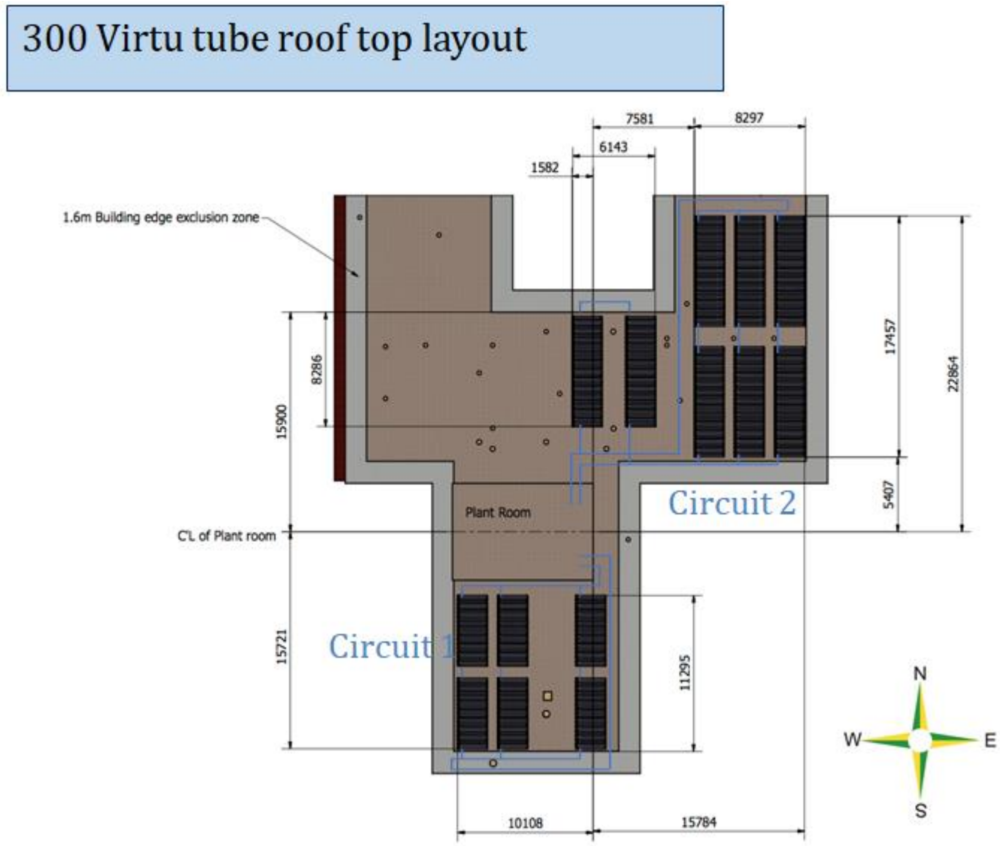


Figure 4 - On Roof Circuit and Tubes Layout

Some factors that must be considered in designing an array layout for Virtu tubes include:

1. Shading – this depends on sun direction, the location of nearby buildings, trees and other objects. In the above example the central plant room caused some shading to the region on the north side of it.
2. Other objects on roof – most roofs have some other features, such as plant, ducts and vents which can block some mounting areas.
3. Edge exclusion and access – many roofs have an edge exclusion zone in which solar collectors cannot be mounted or regions that are not easy to access. In some cases there are access corridors that must be kept clear for other reasons.
4. Proximity to plant room – minimising the distance between the solar collectors and the plant room both reduces costs and heat losses that can result from long pipe runs.

In the above example layout the objective was to mount 300 tubes, but there was not one area that was clear of shading or other obstructions. 2 separate pipework circuits were therefore proposed, which maximised the number of tubes that could be mounted and avoided long pipe runs between them.

The maximum number of tubes that can be connected on a single manifold line is 20. Above this the flow between tubes would become non-uniform (with flow of the central tubes being reduced). In the above layout the tubes are arranged with 2 blocks of 20 tubes in series, with the water flow going through one set of 20 and then through the second. This doubles the temperature rise (delta T) for each water circuit and halves the total flow rate needed, which can reduce pumping and pipework costs (see also section 6.1).

The connections to the end of rows should use the reverse-return connection method (see figure below). This keeps the flow distance the same between different rows and therefore ensures equal flow rate between them. Alternatively (to minimise pipe connection lengths), direct connection can be made (i.e. without reverse-return) but including flow setters to allow the flow rate along each row to be balanced. Flow setters have a visual indicator of flow and a quarter turn adjustment. The visual flow indication can also be useful during commissioning.

Figure 5 - Reverse-Return Connection of Rows

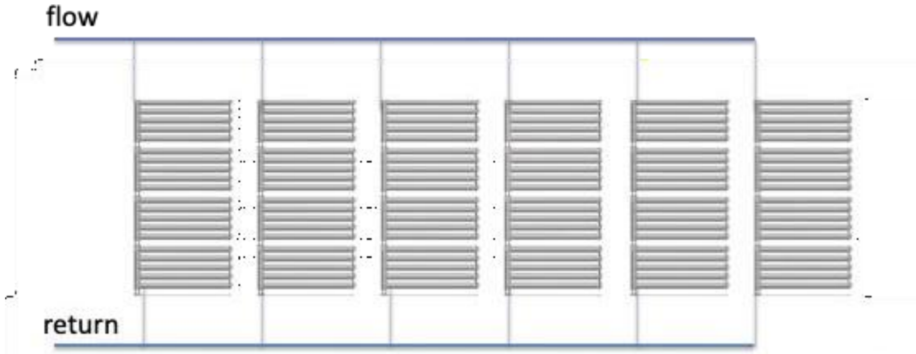


Figure 6 - Direct Connection of Rows (Requires Flow Setters on each row)

5. Roof mounting and connections

The weight of VirtuHOT is 14 kg/tube (see Datasheet in Section 3) and this is sufficient to secure the tube from moving under wind loading except for high wind velocity locations (see section 5.4), without the need for bolting it down or for additional ballast (i.e. it is self-ballasting). For all roof types, it is important to check that the roof or mounting surface is strong enough for the loading of the solar array. A Structural Engineer report should be provided to demonstrate the roof is strong enough to support the weight of the solar array (and any additional ballast), including consideration of average loading and point loading.

5.1 Roof mounting – flat roof

The Virtu support has been designed such that the aluminium frame can be placed directly on a flat roof. This avoids the need for mounting sub-rails and support brackets, which reduces costs both in hardware and in installation labour.

Each frame support 5 tubes and frames can be attached toghether to make a continuous row of up to 20 tubes (or up to 60 tubes if 3 sets of 20 are connected in series). Both tube and reflectors are attached to the frame using M8 bolts.

For flat roof installations where no additional frame ballast is required (i.e. low wind loading conditions) Tube Straps are not required – see sections 5.4, 12.6.1, 12.6.3.

For flat roofs on tall buildings, where additional wind loading needs to be considered, the Tube Band securing mechanism may be required in addition to the Tube Strap (see sections 5.4, 12.6.1, 12.6.4).

Figure 7 - 2 x VirtuHot Frames connected in series during installation

For membrane (e.g. EPDM) roofs, as shown in the above figure, it is advisable to place some spacers or protective layer under the ends or corners of the frame, to protect the membrane. This can be rubber pads at the corners or an additional strip of EPDM as shown above.

The Side Frames are connected together with the Ballast Trays. Up to 9 small ballast blocks (3.1 kg, 200 x 100 x 65 mm) can be placed in each Ballast Tray. The standard frame uses 2 Ballast Trays but an additional 3 can be installed, giving 5 ballast trays for each 5 tubes, giving a maximum of 45 ballast blocks (140 kg). For VirtuHOT HD the maximum ballast trays is 4 per 5 tubes.

5.2 Roof mounting – sloped roof

Mounting on a sloped roof requires the Virtu tubes to be more securely fastened. The aluminium support frame can be secured to rails on the roof or other fixings. The aluminium frame is secured to Cross Rails on the sloped roof. These rails are in turn attached to the roof as part of an in-roof mounting system, such as that shown below.

For sloped roof installations, the Tube Band securing mechanism will be required in addition to a Tube Strap (see sections 12.6.1, 12.6.5). In the unlikley event of tube damage, a mesh guard/grid below the array is also advised as a precaution.

Figure 8 - On Roof Mounting pre-frame fitment

Figure 9 - 60 Virtu Tube Pitched Roof Installation in parallel

5.3 Mounting on vertical facade

Virtu can also be mounted on a vertical wall or façade. Since the absorbers are angled within the tube, the orientation is more optimised to the sun direction and achieves higher efficiencies than would be achieved by a flat panel collector on a vertical wall. The output is best for South facing façades but South-East or South-West façades are also possible. Output on façades is also greater in high latitude locations (as sun elevation angles are lower).

Façade mounting uses the same aluminium frame and tube clamp parts that are used on sloped roofs (see previous section). In this orientation the absorber is angled upwards and the reflector downwards. The result of this is that the reflector gives more power enhancement in winter (when the sun elevation angle is low) than in summer. This flattens the annual energy generation profile, which can provide a better match between heat demand and generation (especially for space heating applications).

Figure 10 - Vertical Facade Mounting

For vertical fascade installations, the Tube Band securing mechanism will be required in addition to the Tube Strap (see sections 12.6.1, 12.6.5). In the unlikley event of tube damage, a mesh guard/grid below the array is also advised as a precaution.

5.4 Wind loading on flat roof

Due to their low profile Virtu collectors do not require bolting down on a flat roof and can be considered to be self-ballasted for most installations. However, in locations where very high wind speeds can occur (typically >70 mph), the collectors will require extra ballast or bolting down. Peak wind speed can be calculated based on location, building height, location on the roof and other geometric factors (such as parapet wall height), as described in the BRE Digest 489. An assessment of wind pressure should be made by a licensed Structural Engineer prior to installation of any Virtu array, but Naked Energy can support installers in estimating ballasting requirements for design and planning purposes.

Computational Fluid Dynamics (CFD) modelling of an array of Virtu tubes has been carried out to determine the wind loading as a function of angle and velocity. The image below shows a typical CFD simulation for 5 Virtu tubes.

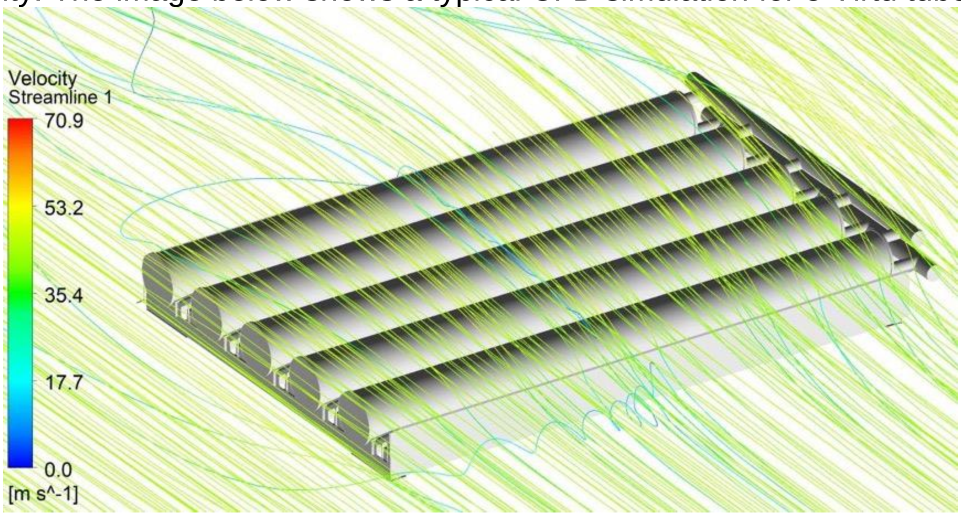


Figure 11 - Computational Fluid Dynamics Simulation

The CFD simulations allow calculation of the X, Y and Z forces on the array and these enable calculation of the lifting and sliding forces. The array shows low lifting force (for all wind directions) and sliding of the array is therefore always the first movement predicted as wind speed is increased. The weight needed to avoid sliding also depends on the frictional coefficient of the roof, which must be measured or assessed based on the roof surface and support materials. The weight per tube of a 10 tube VirtuHOT array (with the Frame and with water manifolds) is 19.3 kg. Therefore, when the sliding calculation shows that a weight larger than this is needed, additional ballast weight must be added in the Ballast Trays. Naked Energy have created an excel based calculator to calculate ballast requirements, along with a Technical Annex to explain the methodology for completing a calculation. These are available from the Naked Energy support team.

5.5 Connections

The water manifolds are connected up along each row. This involves a connection between the 8mm copper pipes on the collector and the 10mm copper manifolds, which is usually done with a 8-10mm reducer compression fitting. The manifold pipes are then connected up between the rows to the 2 pipe runs (flow and return) that go to the plant room and complete the water/glycol circuit.

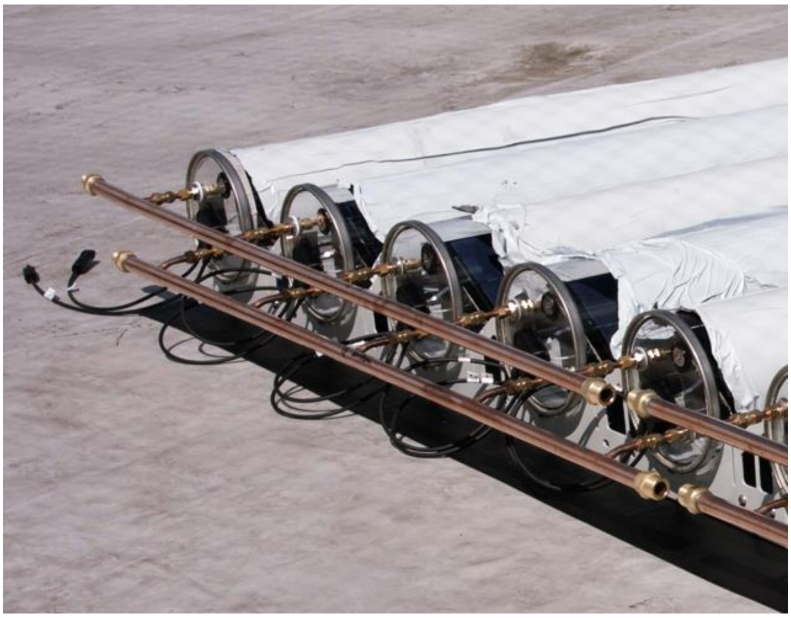


Figure 12 – Cold Return Inlet (bottom of picture) and Hot Outlet Flow (top of picture)

Thermal insulation is also used to cover the pipework and minimise heat losses to the ambient. Insulation must be solar rated (high temperature e.g. EPDM rated to >150°C) and outdoor compatible, so should be UV resistant and not absorb water.

Figure 2 - Fitment of UV Rated Insulation

6. System thermal design

The detailed design of the thermal circuit and the selection of components must be carried out by an experienced solar thermal designer. This section describes some of the design elements that must be carried out but does not give complete details of how to do this design work.

<u>6.1 Flow rate</u>

In order to specify/select the circulation pump, it is necessary to calculate the maximum and minimum total flow rate of the system and the pressure drop. The system should be designed in such a way that the flow rate and pressure within each individual tube stays within the limits set in Table 1 under all reasonably forseable operating conditions.

The flow rate depends on the number of Virtu tubes in the array, the configuration in which these are connected (series/parallel connections) and the desired temperature rise (delta T) at peak power. It is recommended that the temperature rise across each individual VirtuHOT tube is limited to 10-15°C on the sunniest days, as this maximises the thermal efficiency. Based on a peak thermal output of 350 W from a VirtuHOT tube (which will vary with temperature and location), a flow rate of 0.5 l/min per tube will give a delta T of 10°C. Therefore for an array of 100 VirtuHOT tubes (output 35 kW peak) the maximum total flow rate needed for the same delta T would be 100 x 0.5 = 50 l/min.

Max Flow Rate Calculation for a ▲T of 10°C

$$No.\,of\ VirtuHot\ Tubes\ \ x\frac{0.5l}{min} = Max\ Flow\ Rate\ (\frac{l}{min})$$

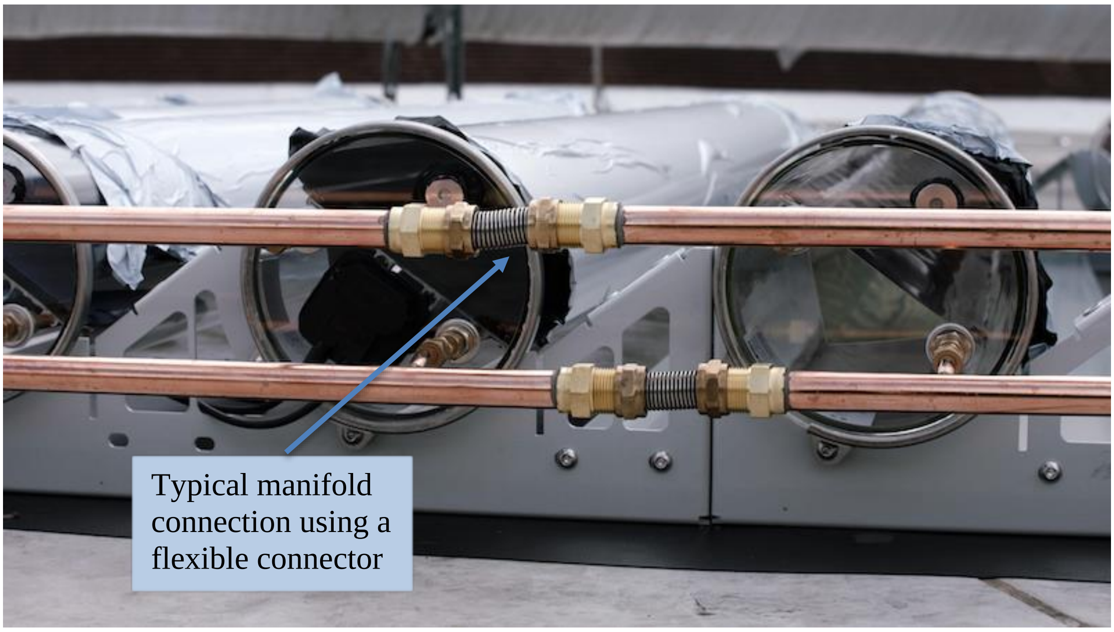


Figure 14 - Fitment of UV Rated Insulation

For some applications a higher peak delta T than 15°C (between flow and return) may be prefered. Raising the delta T from 10°C to 20°C would reduce the total flow rate in the above example from 50 to 25 l/min, allowing a smaller pump and smaller diameter pipework to be used (offering some cost savings). In this case it is recommended to connect 2 or 3 rows of Virtu tubes in series (rather than all in parallel). In the case of 2 rows in series, the flow (outlet) manifold from one row is then connected to the return (inlet) manifold of another and this reduces the total flow of the system by half. With 25 l/min through 2 sets of 50 tubes the temperature rises 10°C across each set, giving a total system delta T of 20°C.

The above photo shows 2 sets of manifolds connected in parallel, the photo below shows them connected in series.

Figure 15 - Fitment of UV Rated Insulation

Here the flow (outlet) manifold from one row is connected to the return (inlet) manifold of another. During each circuit of the array the fluid passes through 2 tubes and this reduces the total flow of the system by half. With 17.5 l/min through 2 sets of 50 tubes the temperature rises 10°C across each set, giving a total system delta T of 20°C.

Connecting 2 rows in series can offer other benefits, since it doubles the flow rate inside each Virtu tube (compared to all parallel connection with the same system delta T), which can help to remove air bubbles and maintain flow uniformity. It can also reduce pipe run lengths for the connections between rows (as shown in the layout example in section 4).

In additional to defining the maximum flow rate, it is also important to estimate a minimum flow rate. While the peak power may be 350 W, the normal power at the target temperature on an average sunny day may be 250 W and on a cloudy/hazy day may be 50-100 W. Based on this minimum power level, a flow rate can also be calculated to give the desired minimum delta T for the application.

Min Flow Rate Calculation for a ▲T of 10°C

$$\frac{0.5l/min}{350\ \text{Watts}}\, x\ (Min\ Watts\ x\ Number\ of\ Tubes) = Min\ Flow\ Rate\ l/min$$

6.2 Pipe diameters

Based on the above calculation of maximum flow rate, the pipe diameters can be defined for the pipework that connect the manifolds and for the flow/return to the plant room. To avoid erosion of copper pipework and also avoid excessive pressure drops, a useful rule of thumb is to keep flow velocities in pipes < 1 m/s. For the above example of a 20 l/min flow rate this requires a pipe external diameter of 22 mm. For 40 l/min the pipe diameter would increase to 32 mm (for the same flow velocity), which would significantly increase the cost of the pipework and fittings.

For the above example of a 25 l/min flow rate this requires a pipe external diameter of 25 mm. For 50 l/min the pipe diameter would increase to 35 mm (for the same flow velocity), which significantly increases the cost of the pipework and fittings.

6.3 Pressure drop

To specify the pump, the pressure drop as well as flow rate range is required. Pressure drop can be calculated by adding up the contribution of each system component.

The pressure drop due to the pipework can be calculated using an online calculator: http://www.pipeflowcalculations.net/pressuredrop.xhtml
The pressure drop due to a Virtu tube is approximately 0.1 bar (so 2 rows of tubes in series gives 0.2 bar). The pressure drops due to pipe runs, bends, manifolds and Virtu tubes should be added together to work out the total pressure drop across the pump in normal operation. This will usually have a total in the range 0.5-1 bar.

If the array is at a higher elevation than the plant room, then there will be an additional pressure drop between plant room and array, equal to 0.1 bar for each meter of height. For example, if the array is 4 floors above the plant room and this equals a 16 m height difference, there will be a 1.6 bar pressure difference. This 1.6 bar pressure does not need to be added to the pressure drop used to size the pump (since the system is a circuit, so the pressure drop to raise the glycol up to the array is cancelled by the pressure gain on returning to the plant room). However, it should be taken into account when setting the absolute pressures when charging the system (see 6.5 below). When specifying a pump for a system with a large vertical height a pump should be selected with a slightly higher pump pressure capability, to allow some margin across the range of operating conditions. A margin of 20% (above the calculated pressure drop) is usually sufficient (e.g. increasing a 0.5 bar pressure drop to 0.6 bar), but the pump supplier should be consulted in cases when the array is >20 metres above the plant room, to confirm a suitable pump selection.

6.4 Pump

The flow rate range (maximum and minimum) and pressure drop can then be used to specify a suitable pump for the circuit, based on pump manufacturers' published pressure:flow curves. Different pump types offer different dynamic range between maximum and minimum flow rate. PWM (pulse-width modulated) controlled pumps (such as Wilo Solarblock pump stations) are a good choice for enabling a wider dynamic range, giving control of flow rate down to 20-30% of maximum.

If a glycol solution will be used, a glycol compatible pump should be selected. In some installations 2 pumps are specified and they are sometimes supplied in a single pump station. The advantages here are to further increase the controllable range of flow rates (especially if one pump is larger than the other) and also to give a backup if one pump fails. A pump station also often includes a connection point for filling, a manual pressure gauge and a connection for an expansion vessel.

6.5 System pressure management

Virtu should be used only with sealed pressurised systems (it has not been designed for use with drainback systems). The pump selected will have a compatible pressure range, with a minimum backing pressure for good pump efficiency. The pressure behind the pump must be above this value and in front of the pump it will be higher by the amount of the pressure drop due to the pipework and collectors. So in the example above the normal pressure behind the pump could be 1.5 bar and in front of the pump (at maximum flow) 2.0 bar. Up at the array the pressures would be 0.4 bar lower than these lower due to the 4 m height increase (so 1.6 bar in the flow line and 1.1 bar in the return line).

As the temperature of the sealed fluid system varies the pressure will also change. To keep pressure within a desired range for good operation, an expansion vessel should be included, which has a flexible membrane that can expand to accommodate volume change. The size of the required expansion vessel depends on the system size and type and can be calculated based on the fluid volume and potential temperature rise, using online system design guides e.g.: www.barillasolar.co.uk/assets/download/index/assets/28/
Ideally the expansion vessel calculation should be based on the worst case over-heating case in which flow stops during maximum sunshine intensity (known as a stagnation condition). In this stagnation situation the heated fluid in the system expands, but inside the Virtu collectors the water/glycol can be vaporised to steam, giving an even larger expansion. The expansion vessel should be pressurised to match the system pressure such that it is approximately 25-50% full of liquid under normal operating conditions: this allows the fluid to either contract or expand as temperature varies.

In addition to the expansion vessel, pressure relief valves (PRVs) should be included on the system, to release system pressure in an unusual fault condition. A 3 bar PRV is recommended with Virtu HOT, located in the plant room, although with systems with a large height distance between plant room and array a higher pressure rated PRV may be required (e.g. 6 bar). A PRV is often included as part of the pump set and is usually on the higher pressure side of the pump. For systems with a long pipe run from plant room to array it is good practice to also include a PRV at the array. The released fluid coming from the PRVs can be very hot in fault conditions (e.g. stagnation), so the PRV should vent into a containment vessel or be piped to a safe location.

6.6 Air vents

During system filling, it is important to exclude air from the water/glycol circuit. Air locks can result in the fluid not circulating properly, leading to some parts of the system stagnating. The presence of air in the system can also lead to corrosion. It is therefore helpful to include automatic air vents in the system, to help exclude air during system commissioning. These have a membrane that lets air out but not water. Air vents should be positioned at the highest points of the system, where air builds up. They should be included both at the array (on the end of the manifolds) and also in the highest point of the plant room. It is recommended to use air vents with a manual valve, to allow them to be isolated from the system. This is because it is possible for the membrane to dry out and then the vent can let air back in. It is recommended to have the manual open during system filling and the first few weeks of operation of a new system. After that the manual valves should be closed and only opened periodically as part of monthly maintenance checks.

Figure 16 - Flowmeter with analog display

Figure 17 - Automatic Air Vent Example on Hot Flow (outlet)

6.7 Sensors

It is essential to include sensors to monitor and control the system operation, both during commissioning and during ongoing operation, and this is a requirement of the VirtuHOT warranty. The system controller (see next section) will require temperature sensors, to allow the pump and valves to be controlled for optimum system performance. In addition, a flow meter or a heat meter will enable the thermal power to be monitored and recorded, and allows alarms to be set if there is no flow (during sunny conditions). In addition to an electronic flow or heat meter, a visual flow sensor (a glass window or rotameter showing fluid flow) is helpful during commisioning, to allow easy confirmation of when fluid is flowing and whether it is in the correct direction. Finally it is important to include some pressure sensors. Most pump stations have a visible analog pressure sensor, which is helpful when filling the system and for confirming it is leak tight during commissioning. A digital pressure sensor is also essential, to raise software alerts if the system pressure falls later on during operation.

6.8 Fluid

In climates that have freezing temperatures, a water/glycol mix must be used to fill the water circuit, to avoid the risk of freezing damage. It is essential to avoid fluid freezing as this can rupture pipework, both inside the Virtu tubes and external pipework. A glycol concentration of 25-40% is required to give protection in the range -10 to -20°C. Propylene glycol should be used in preference to ethylene glycol (due to its lower toxicity and environmental impact) and a glycol product should be selected that has been developed for solar applications (high temperature compatible) and has corrosion inhibitors to avoid corrosion of metals used in solar circuits. A premixed glycol solution (diluted to the correct concentration) is recommended, but if concentrate is used or if a glycol solution needs to be further diluted, de-ionized or de-mineralized water should be used.

For climates that are frost-free, an alternative to glycol is to fill the system with de-mineralized water with a corrosion inhibitor additive. This is even possible in regions that sometimes have freezing temperatures, but in this case there needs to be a frost prevention approach in the system controller e.g. the controller actuates the pump (with continuous or pulsed flow) to run when the ambient temperature falls close to freezing point. While this approach saves on the cost of glycol and improves heat transfer efficiency slightly, it increases the annual pumping power consumption and also wastes some heat.

It is good design practice to include a particle filter in the system. Even in a closed loop system, particles can build up, as result of pump and valve operation or corrosion and could cause blockage or pump failure. In large systems with higher likelihood of particle contamination, the filter should be serviceable during normal operation (i.e. the filter is switcheable and can be opened and cleaned without having to reduce system pressure), but note that this type of filter can be expensive. For small systems, even a cheap filter that can only be cleaned at the annual maintenance check is beneficial.

6.9 Stagnation protection

The system must include a stagnation protection mechanism to ensure that the solar collectors do not overheat during periods of low demand. In most cases, the best approach is to install a fan-cooled-radiator heat dump, which is engaged when the array temperature goes above a threshold temperature (recommended 85°C). The heat dump must be installed on a separate branch of pipework that tees off from the main solar pipe circuit. A motorized three-way valve is used to divert flow to the heat dump (instead of to the tank) in the event that the array temperature reaches the threshold temperature. Many solar controllers (e.g Resol Deltasol BX Plus) have a built-in heat dump function to control the divert. The fan should be switched on every time the divert is triggered. This can be done by installing a contactor on the fan's power supply, which is triggered by the same relay that triggers the divert. It is not advisable to power the fan directly from the solar controller.

Different systems may require different stagnation protection strategies. Please consult Naked Energy if you would like to install an alternative stagnation protection instead of a heat dump.

Failure to properly protect the solar collectors from overheating may result in a void of the product warranty. Please consult the Virtu warranty document.

6.10 Bypasses

To optimise delivery of heat to the building system, it can be beneficial to add other system elements. When the thermal array is too cold to supply useful heat to the building e.g. on cloudy days or during morning heat up, it can be very useful to include a bypass line at the heat exchanger or thermal store, to avoid cooling down of the thermal store. Below a defined target temperature, the controller will divert flow along a bypass using a 3-way valve, which will switch the other way once the target temperature is reached.

6.11 Legionella risk

When designing systems for provisions of sanitary/domestic hot water, care should be taken to ensure that the installed solar hot water system does not create a legionella risk, which could be hazardous to the health of the hot water users. Solar pre-heat systems in particular must be designed carefully, since water is stored at temperatures above the mains temperature but often below 60°C, which creates the highest risk of bacteria growth. CIBSE have published guidance for the avoidance of bacteria growth in solar hot water systems [see reference 1 at the end of this section], and have covered the issue of legionella and bacteria extensively in reference 2. The system designer is strongly advised to read these or similar sources dealing with the issue. In general, the system should be designed so that either:

a. The preheat tank uses a DHW coil or external heat exchanger, to ensure that potable water is not stored in the body of the tank, essentially reducing the volume of warm water that is allowed to be stagnant in the system, or
b. The pre-heat tank is periodically pasteurized by either an internal element heater, or a purge cycle between the solar store and the primary DHW cylinder, or an inline heater.

Local regulations may dictate which approach is used. The guidance provided in this installation manual is advisory. Installers should seek advice from experts or expert literature on the subject of legionella and bacteria formation in solar hot water systems.

[1] CIBSE, The Solar Heating Design and Installation Guide, 2016, https://www.cibse.org/knowledge/knowledge-items/detail?id=a0q20000008I7fjAAC

[2] CIBSE TM13: Minimising the Risk of Legionnaire's Diseas and Health & Safety Executive ACOP L8.

7. System controls and data logging

A system controller is required to control the pumps and valves in the fluid system. This can be carried out by a commercial solar thermal controller, a building management system (BMS) or a bespoke system controller and Naked Energy have used all 3 of these approaches on installations of Virtu. The simplest and recommended control approach is to use a commercial solar thermal controller, such as the Resol DeltaSol BX+. This has standard data inputs and outputs and offers a range of standard and optional control modes that give flexibility with system design and operation. In addition to controlling the pump and valves, the controller will give alarm codes if certain parameters go outside of normal control limits e.g. temperature or pressure too high or too low. Controller setup is described in more detail in sections 13.3 and 14.

Resol also make a data logger (Resol DL2 Plus) that interfaces with the controller and records the sensor parameters and control states against time. This allows performance to be monitored in real time and analysed, which is essential for detecting fault conditions and valuable for optimising system control and performance. Real time monitoring and data storage (of temperature, flow rate and pressure data) are a requirement of the VirtuHOT product warranty.

8. Equipment list

In preparing an installation it is useful to draw up an equipment list, to ensure that all the necessary hardware has been sourced and is available in time. The following is a typical list.

Supplied by Naked Energy:

- VirtuHOT tubes
- Reflectors – these are supplied separately from the Virtu tubes.
- Support frames – including Side Frames and Ballast Trays
- M8 Screws to assemble frame and attach tubes and reflectors
- Manifolds – the standard design connects 5 Virtu tubes, so 2 manifolds are required for each 5 tubes
- Connectors for 8-to-10 mm water connections to manifolds (brass compression fittings)
- Connectors between manifolds – flexible stainless steel connectors are recommended for these connections

Other equipment for roof installation:

- Pipework for connecting the rows and for the flow and return lines to the plant room.
- Connectors between manifolds and row connection pipework – the connector size will depend on the total flow rate and pipework diameter. Various types of solar compatible connectors are available that are quick to connect with high reliability – such as Press-fit crimp connnectors.

- Pipe insulation (solar thermal and outdoor compatible type) for the manifolds, row connections and plant room pipework.
- Tape and/or glue for sealing joins and edges or pipe insulation
- Earthing cable and clamps for earthing the manifolds
- Support brackets to support manifolds
- Automatic air vents (AAV) including isolator valves
- Temperature sensor pockets – of suitable length so that the sensor tip is positioned in the centre of the fluid flow
- Earthing cable and clamps for earthing the frame and manifolds

Other equipment for plant room:

- Pump set
- Thermal store and/or buffer tank
- Heat exchanger or coil (interface to building demand side)
- Expansion vessel
- Pressure relief valves (PRVs) – usually 6 bar rated (sytem dependent) – including drain line or small tank to connect PRV to
- 3-way valves and check valves based on system design e.g. for thermal store bypass
- Temperature, pressure and flow sensors
- Heat meter
- Controller and data logger
- Glycol – based on system volume calculation (see also section 6.8)
- System cleaning fluids (see section 13.1)

9. Site access, risk assessment and installation timeline planning

Ahead of the installation, a detailed plan should be created defining the activities, manpower and timeline. This should be based on the steps described in sections 12 and 13, but may also include other elements of site preparation, such as delivery of the kit to site and storage of parts on site. Delivery of the tubes to the roof may require a crane or other lifting equipment, which may only be possible at certain times of day. Storage of the kit on site, site access and access control should also be considered and contingencies planned for different possible types of weather.

Approvals should also be sought from site and building owners and authorities, to confirm agreement with the design of the planned array and the schedule and approach for the installation. This should include an assessment of complicance with Building Regulations and where applicable Planning Permission from local authorities.

A detailed risk assessment should be completed by the installation site manager, taking account of all steps in the installation and commissioning plan. The risk assessment should be approved by the customer or site controller ahead of time and should form the basis of a safety briefing that will be given to the installation team before work commences. The risk assessment should define all potential risks and identify control measures and PPE that should be worn by the installation team. All installation and maintenance personel should also be made aware of all risks listed in section 2 and on the installation risk assessment.

10. PPE list

The personal protective equipment (PPE) list should be derived from the risk assessment. Typical PPE is likely to include:

- High visibility jackets
- Safety glasses (especially for when handling the Virtu tubes, which are under vacuum and could therefore result in flying pieces of glass if broken)
- Safety shoes or boots (with toe protection)
- Hard hats (only if required by the risk assessment)
- Gloves – manual handling gloves and disposable gloves (for handling glycol)
- Kneeling pads

11. Tools list

The following tool list is proposed:

- Filling station (for filling system with glycol and de-aerating)
- Crimp tool (if crimp pipe fittings are used)
- Adjustable spanners and Hexagonal keys
- Knife and/or scissors (for cutting tape, insulation)
- Screwdrivers (for adjusting any support clamps)
- Heat sink compound (for temperature sensor pockets)
- Glass cleaner fluid
- Paper towel and cloths
- Sealing compound and/or PTFE tape for compression fittings
- Foot pump to adjust pressure in expansion tank
- Tarpaulins to cover array in case of fault or maintenance

12. Installation sequence

Installation of Naked Energy products should only be carried out by qualified personnel. The installation, starting up, and servicing of solar heating and power equipment can be hazardous and requires specific knowledge and training. Improperly installed, adjusted or altered equipment by an unqualified person could result in death or serious injury. **The main safety risks associated with VirtuHOT are listed in section 2 of this document.**

This section lists the installation tasks for the VirtuHOT thermal array, but does not include the installation of plant room equipment. The order of the tasks is proposed based on recent pilot system installations, but some tasks could be carried out in a different sequence.

12.1 Mapping out installation array area

Based on the array plan it is useful to measure and mark out the locations of the rows of Virtu tubes and confirm the orientation with respect to the building and to South. Please note that compass apps on phones can be quite inaccurate, so it important to use a proper calibrated compass or align to a building feature of known orientation.

The drawings below show the layout dimensions for VirtuHOT. The recommended minimum service corridor between rows of tubes is 50 cm and this should be used between each row if all the tubes are oriented the same way. If the orientation (between left and right handed) is alternated, the tubes can be arranged back-to-back, with a “right-handed” row of tubes next to a “left-handed” row, so that the blank ends of the tubes meet for these 2 rows. In this case, the central corridor at the blank (non-manifold) end can be reduced to just 25 cm. With 50 cm corridors at the manifold end, this gives a combined average corridor of 37.5 cm per row.

Figure 18 - Orientation and Service Corridor distances taken from VirtuHOT Spec Sheet

12.2 Inspecting and transporting the Virtu tubes

The Virtu tubes will be delivered on pallets, usually containing 30 tubes stacked on carboard support formers with edge protection and shrink wrapped.

The Virtu tubes should be inspected on delivery for any damage to the packaging, if damage is evident then affected tubes should be carefully inspected.

Any damage to the tubes or other components should be photographed and the shipment carrier notified in writing. Do not install any tubes or components that have been damaged, either from shipment or during installation.

The Tubes should be unloaded from the pallets by hand by 2 people. Care must be taken when moving the tubes from point of delivery to the installation site. It is advisable to carry individual tubes in a tube transport bag that is available from Naked Energy.

Individual tubes will be delivered with a protective film covering the front side, shading the absorber from direct sunlight. This avoids over-heating of the tube in sunny conditions before the water/glycol flow has been turned on. It is therefore important that protective film is kept in place until commissioning has been completed and the system has been confirmed to run reliably under automatic control.

12.3 Assembling the Support Frame to the Ballast Trays

The Left and Right Support Frames are connected to the Ballast Trays (see photo below) using M8 x 16 mm Socket Cap Screws (note: not the 30 mm Screws). The front and back Ballast Tray positions are always used. If additional ballast is required (for wind loading – see section 5.4) then up to an additional 3 Ballast Trays can be connected in the centre of the frame. Ballast blocks should be loaded into the trays before the Virtu Tubes are mounted – see also figure in section 12.5.2. Up to 9 small ballast blocks (3.1 kg, 200 x 100 x 65 mm) can be placed in each Ballast Tray. With 5 trays this gives a maximum of 140 kg ballast per 5 tubes.

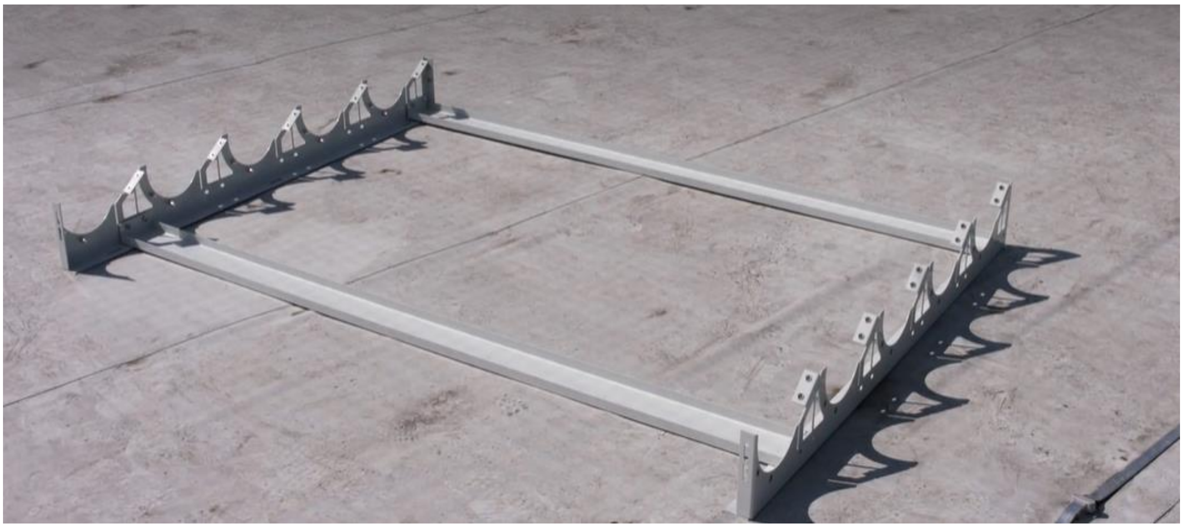


Figure 19 - VirtuHOT Frame with top and bottom Ballast Tray Fitted

If the roof has a membrane finish (e.g. EPDM) it is recommended to put a protective layer under the contact faces of the frame to roof surface, such as rubber pads or an additional strip of EPDM (see photo below).

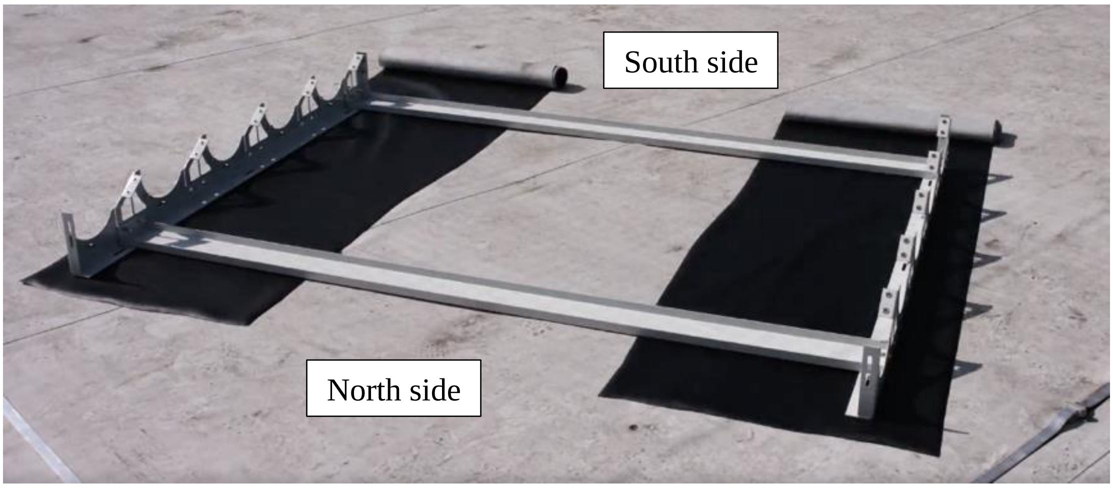


Figure 20 - Frame alignment towards south and protective material between roof and frame

Double check the frame orientation and alignment angle to South. The above photo is taken from the back of the array (i.e. the North side). Reflectors face North and absorbers face South (for northern hemisphere locations).

<u>12.4 Connecting Support Frames together</u>

Based on the number of tubes in each row (in the array design), additional frames should be attached together using M8 x 16 mm Socket Cap Screws (note: not the 30 mm Screws). For VirtuHOT HD M8 nuts are also required (as the HD frame does not have captive nuts).

<u>12.5.1 – *VirtuHOT* – Attaching Back-of-row Reflector</u>

For VirtuHOT, it is recommended to attach a Reflector vertically at the back of each row of frames. This is not needed for the strength of the frame, but is beneficial in reducing wind loading and closing off the frame enclosure (e.g. from nesting birds). The Front-of-row Reflector should be attached in step 12.11 but the Back-of-row Reflector must be fitted before the Tubes, as it requires both M8 x 16 mm Socket Cap Screws and M8 nuts (there are no capitive nuts on this end of the frame). The M8 nuts should be attached on the <u>outside</u> of the frame (to avoid a clash with the glass Tube next to it) – see photos below.

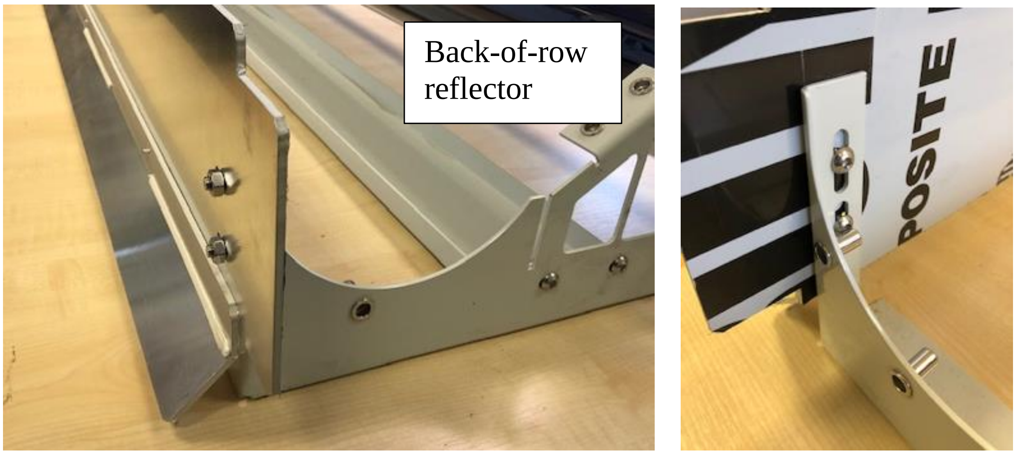


Figure 21 - Back of Row Reflector Fitment

<u>12.5.2 – *VirtuHOT HD* – Attaching End Plates</u>

VirtuHOT HD does not have any reflectors. Therefore, to support the Side Frames and enclose the ends of the rows, 2 aluminium End Plates are fitted. These require M8 x 16 mm Socket Cap Screws and M8 nuts (since the HD frame does not have captive nuts at the ends). The nuts should be positioned on the inside of the frame. The figure below shows the HD frame with 4 ballast trays, each filled with 9 ballast blocks.

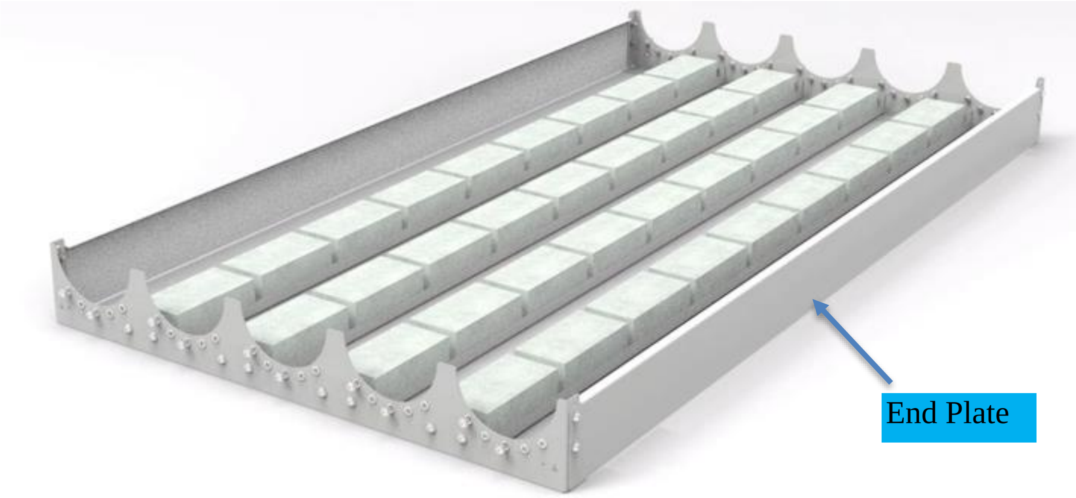


Figure 22 - VirtuHD End Plate Fitment

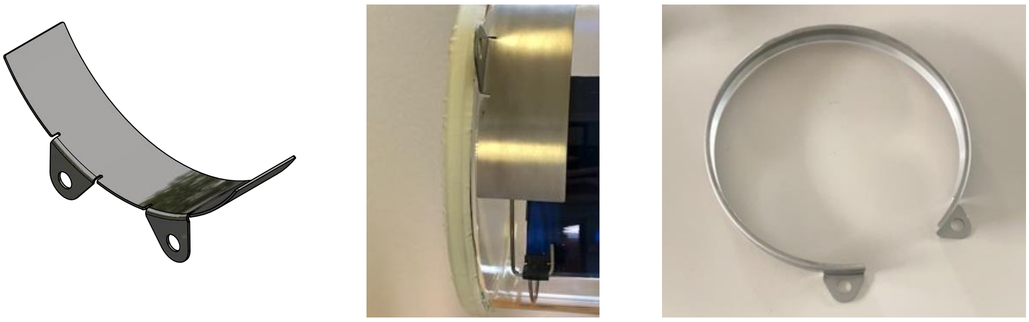
12.6 Mounting the Virtu tubes on the frame

12.6.1 General Mounting Arrangement

When locating Virtu Tubes in to the frame the frame, this should be undertaken by 2 people, one at each end of the tube.

Figure 23 - VirtuHOT during Tube Fitment

A Tube Guide (see image below) is pre-bonded to the tube during manufacture, this is to spread the load on the glass where it rests on the frame.



Tube Guide | Tube guide bonded to glass Tube | Tube Strap

Figure 24 - Tube Guide, Strap and End Tape

The Tubes will be located in to the frames with the Tube Guide facing downwards such that the two holes in the Tube Guide line up with the two corresponding captive nut holes in the side frames. There will be a space of approximately 10mm between each tube guide and the side frame.

On certain installation types, such as flat roofs on tall buildings with high wind loading, sloped/pitched roofs or vertical facade installations, an additional stainless steel Tube Strap (with or without Tube Band) is used to secure the tubes mechnically to the frame.

For flat roof installations where no additional frame ballast is required (i.e. low wind loading conditions) Tube Straps are not required – see section 12.6.3.

For flat roofs where high windloading has been calculated (i.e. tall buildings, buidings in some coastal or exposed locations), the stainless steel Tube Strap alone is utilsed (see image above) – see section 12.6.4.

For sloped/pitched roofs or vertical facade installations, the Tube Strap with Tube Band is used, this provides additional mechanical integrity for these installation environments (see image below) – see section 12.6.5.

End Cap Tape installed around End Cap

Standard Tube Strap fitted to glass end cap and Tube Guide

Tube Strap & Band fitted to end cap and Tube Guide

Figure 25 - Tube Guide, Strap and End Tape

Tube Straps are not pre-installed on VirtuHOT or VirtuHOT HD systems. End Cap Tape (adhesive white glass-fibre tape) must be attached around the circumference of each glass end cap prior to the Tube Strap being fixed around an end cap.

12.6.2 Adjusting Absorber angle (VirtuHOT HD only)

For VirtuHOT HD, which is typically used for sloped roof applications, the absorber angle can be set to 0°, 20° or -20° thus allowing adjustment for differing roof slope angles. There are attachment locations (captive nuts) in the HD Side Frames for these angles.

Figure 26 - Tube Angle is pre-set to 35° for flat roof installations

For VirtuHOT the Absorber Angle is pre-determined due to the position of the pre-bonded Tube Guides. This ensures the Absorbers are at 35° to the horizontal for flat roof installations when attached to the Support Frame.

12.6.3 Flat Roof Installations - Attaching the Tubes to the Support Frame

For flat roof installations where no additional frame ballast is required (i.e. low wind loading conditions) Tube Straps are not required.

The Tubes will be located in to the frames with the Tube Guide facing downwards such that the two holes in the Tube Guide line up with the two corresponding captive nut holes in the side frames. There will be a space of approximately 10mm between each tube guide and the side frame.

Attach the Tubes to the Frame using M8 x 30 mm Socket Cap Screws. These pass through the Tube Strap and Tube Guide into the captive nuts within the Side Frame. Tighten the screws fully into the blind captive nuts, this will leave a 10 mm space between the Tube Guide and the Side Frame.

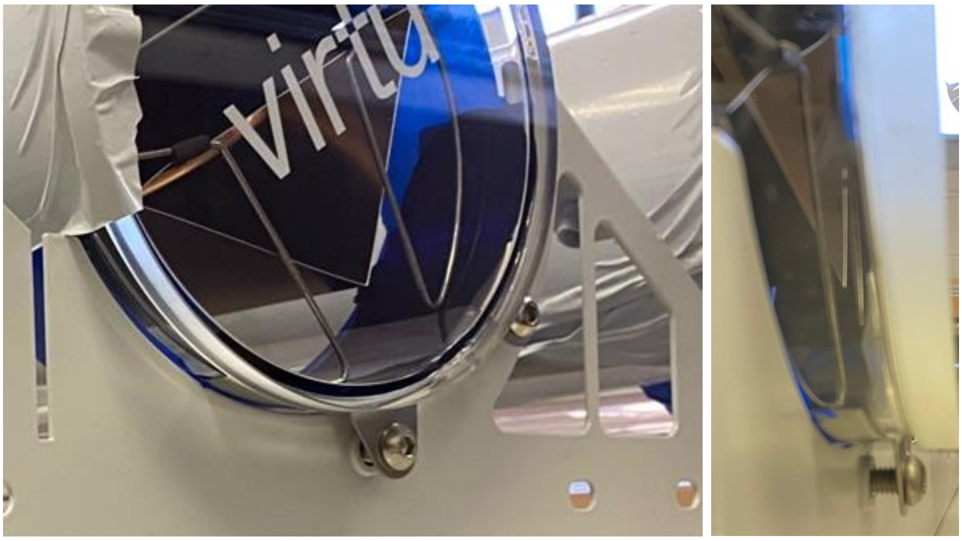


Figure 27 - Fitment of Tube Guide into Side Frame

12.6.4 Flat Roof Installations (high wind load) - Attaching the Tubes to the Support Frame

For flat roof installations where high potential wind loading has been calclulated (i.e. tall buildings, buidings in some coastal or exposed locations), Tube Straps will be required.

The Tubes will be located in to the frames with the Tube Guide facing downwards such that the two holes in the Tube Guide line up with the two corresponding captive nut holes in the side frames. There will be a space of approximately 10mm between each tube guide and the side frame.

End Cap Tape (adhesive white glass-fibre tape) must be attached around the circumference of each glass end cap prior to fitting a Tube Strap.

Locate the Tube Strap over the end cap such that the Tube Strap end flanges and holes holes line up with those of the Tube Guide and Side Frame.

Figure 28 - Fitment of Tube Strap into Side Frame

Install the first M8 x 30mm socket cap screw through the tube guide/tube strap holes into the lower of the two threaded captive nuts in the side frame. Press the tube strap in to position over the second captive nut hole to fit the second socket head screw. Tighten the screws fully into the blind captive nuts, this will leave a 10 mm space between the Tube Guide and the Side Frame.

<u>12.6.5 Sloped Roof/Vertical Facade Installations - Attaching the Tubes to the Support Frame</u>

For sloped roofs and vertical facades a Tube Strap <u>with</u> Tube Band will need be to be installed at each tube End Cap, this provide additional mechanical integrity for sloped roof and vertical façade installation environments.

The Tubes will be located in to the frames with the Tube Guide facing downwards such that the two holes in the Tube Guide line up with the two corresponding captive nut holes in the side frames. There will be a space of approximately 10mm between each tube guide and the side frame.

End Cap Tape (adhesive white glass-fibre tape) must be attached around the circumference of each glass end cap prior to fitting a Tube Strap.

Installation of the Tube Strap <u>with</u> Tube band will require installation of the front end of row reflector support and location of reflectors to their respective positions (but reflector securing screws not fitted at this point) - see section 12.11.

When installing the Tube Straps with Tube Bands, it is advised to first peel back 40mm of tube protector film from each end of the tube (the Tube film must not be peeled further back than 40mm), Similarly peel back the reflector film from each end to just past the reflector fixing holes.

Figure 29 – Peel back tube film (no further than 40mm)

Locate the Tube Straps over the end cap such that the Tube Strap end flanges and holes holes line up with those of the Tube Guide and Side Frame.

Loosely install the first M8 x 30mm socket cap screw through the tube guide/tube strap holes into the lower of the two threaded captive nuts in the side frame. Press the tube strap in to position over the second captive nut hole to loosely fit the second socket head screw to hold the Tube Strap in place. Repeat this for all Tube Straps.

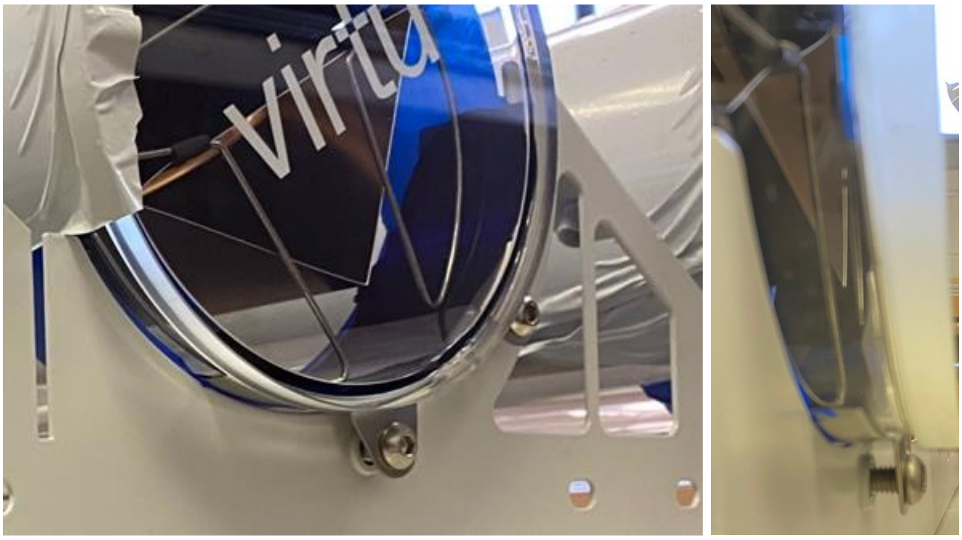


Figure 30 - Fitment of Tube Guide into Side Frame

The stainless steel Tube Band is a ‘T’ shaped stanless steel band with flat eyelets at each long end with a short short branch midway between the two eyelets. The Tube Band is unversal and can be used for either right side or left side fitment.

At the end of the short branch on the Tube Band,a hook has been formed. This must be fitted over the outer edge of the Tube Strap, approximately midway around the Tube Strap perimeter, ensuring that the branch hook and edge of Tube Strap are securely connected (see images below).

Begin working from the right hand side of the top/uppermost Tube, fit a M8 x 16 mm socket cap screw to the lower fixing hole of the reflector to secure the reflector. Starting from this location will save potential later adjustment as you will note that the hole in the associated reflector is round whereas the left side is slotted.

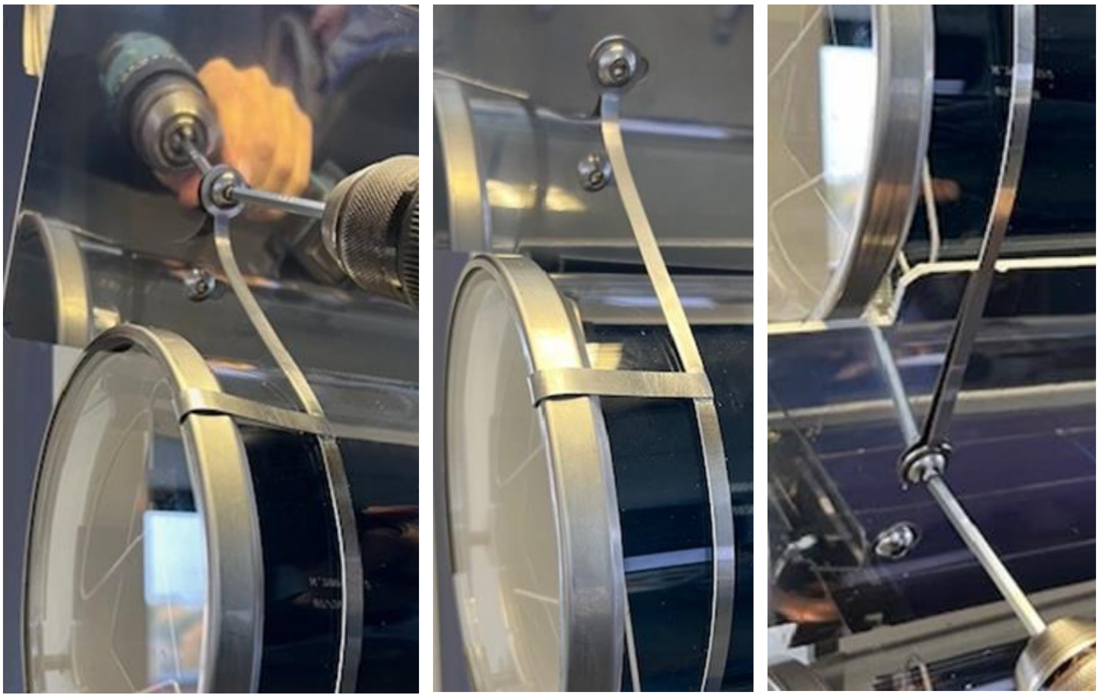
Tube Band | Tube Band hook and end eyelet | Tube Band hook locating under outside edge of Tube Strap

Figure 31 – Tube Band and hook fitment

Securely fit the branch hook of the Tube Band in to the outer edge of the Tube Strap. Fold the branch part of the Tube Band flat to the surface of the Tube, ensuring the hook end is still fully engaged in the Tube Strap.

Form the stainless steel band associated with the uppermost eyelet to follow the curvature of the Tube towards the upper fixing hole in the Reflector above the Tube.

Using a M8 x 16 mm Socket Cap Screw, fix the stainless steel band eyelet to the reflector via the captive nut within the reflector support bracket, tightening the socket cap screw to ensure the eyelet is secure to the reflector and that the stainless steel band and eyelet are not distorted (see images below).



Fixing upper eyelet to reflector above Tube | Fold band around tube to lower lower fixing point | Fixing lower eyelet to reflector below.

Figure 32 - Fitment of Tube band to Reflectors

Tighten the two Tube Strap screws fully into the blind captive nuts in the Side Frame, this will leave a 10 mm space between the Tube Guide and the Side Frame.

Form the remaining stainless steel band associated with the lower eyelet to follow the curvature of the Tube towards the upper fixing hole in the Reflector below the Tube, passing the band over the Reflector such that the eyelet sits over the upper reflector mounting hole.

Do not secure the eyelet to the lower Reflector at this point as the tube band upper eyelet for the Tube below will also need fitting in to this Reflector fixing hole.

Repeat the process above for the tube below (on the righthand side) but when fixing the upper band eyelet to the Reflector, ensure that the M8 x 16 mm Socket Cap Screw passes through both the lower band eyelet from the Tube above and the upper band eyelet from the Tube below. Tighten the socket cap screw to ensure the eyelets are secure to the reflector and that the stainless steel bands and eyelets are not distorted.

This will then complete the securing of the upper Tube.

Repeat the process for all right hand side Tubes.

Then complete the same process for all the left hand sides of the Tubes, again starting from the top/uppermost tube.

Ensure all Reflector and Tube Strap fixings are tightened.

12.6 Attaching Manifolds

The Manifolds are attached to the 8 mm copper pipe ends using 8-to-10 mm brass compression fittings. Before attaching it is important to check the ends of the copper pipes for dents or scratches that could cause a leak. If there are any dents or scratches that cannot be smoothed out it is better to remove the Tube and replace with a good one.

Figure33 - Manifold Connection via 10mm to 8mm reducer Compression Fitting

When attaching the brass compression fittings it is important not to apply excessive force that could damage the feedthroughs (where the pipe goes through the glass end cap). It is also important not to over-tighten - it is better to tighten more later if there any leaks when filling the system. If a fitting is over-tightened (damaging the pipe) it can become impossible to fix the resulting leak.

The flow to the array is connected to the Bottom Manifold and the return to the plant room is connected to the Top Manifold. The Manifolds are connected as shown below, so that the water/glycol travels upwards (from flow to return) – this helps to clear any air bubbles during filling.

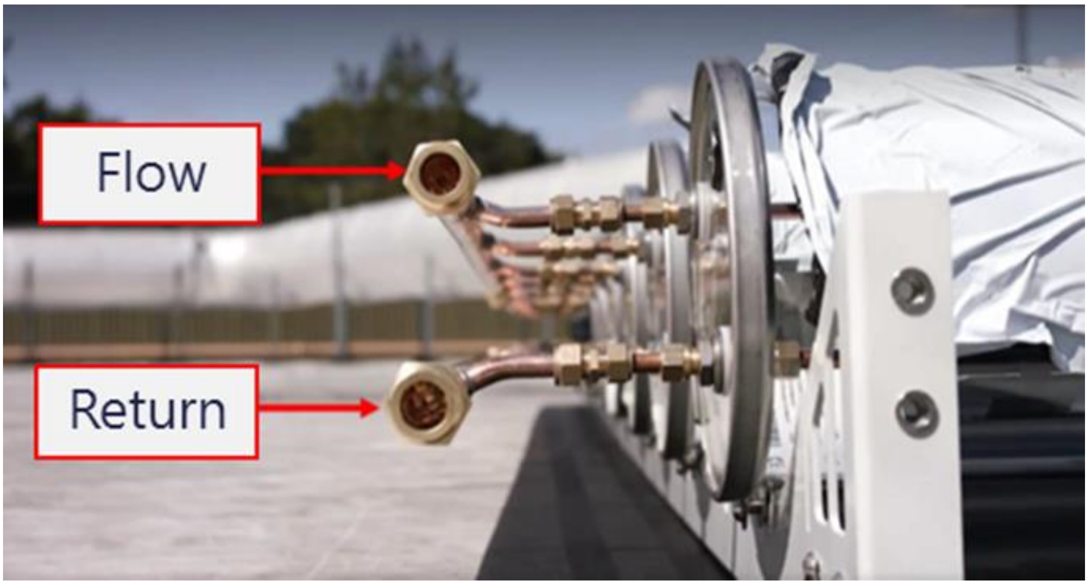


Figure 34 – Flow Manifold (into tube) and Return Manifold (back to Plant Room)

12.7 Connecting Manifolds together

Up to 20 tubes can be connected together in parallel (see section 6.1 for parallel and series connections). Manifolds are connected together using flexible stainless steel connectors (see photo below). It is important to use suitable gaskets that are rated for high temperatures (>150°C) and for use with glycol.

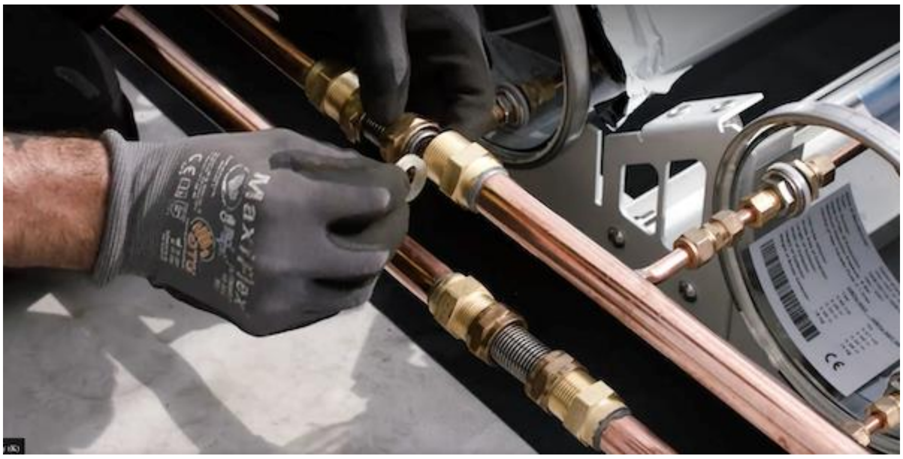


Figure 35 - Fitment of Flexible Connectors between each bank in series

12.8 Connections to the ends of Manifolds

Connect the inlet pipe (coming from the plant room) to one end of the Bottom Manifold. Connect the outlet pipe (going to the plant room) to the other end of the Top Manifold. It is important to connect these to opposite ends of the row to ensure uniform flow between each of the Virtu tubes.

Figure 3 - Return to Plant Room from Hot Return pictured along with Blanked End on Cold Feed

The other end of each Manifold should be blanked off, either using a gasket fitting (the 22 mm Manifold has a BSP flat face DN16 connector on each end) or by cutting off the BSP connector and adding a blank compression fitting.

An Automatic Air Vent (AAV) should be attached at the end of the Top Manifold, to allow any air bubbles to escape (this is the highest point on the array pipework). Compression, gasket or crimp fittings can be used to connect up any remaining pipework back to the plant room.

12.9 Supporting the Manifolds and return pipework

If both connections to the plant room need to be at one end of the row (this will depend on the array and roof layout), one of the Manifolds will need to be routed back to the other end of the row. This can be done with a return pipe under the 2 manifolds, as shown in the photo below.


Figure 4 – U-bend Manifold Routing

The manifolds should be supported using a vertical metal stud and circular plastic clips. This support can be mounted from rails on the roof, as shown on the photo above. Alternatively it can be supported from a bracket mounted on the Side Frame (as shown in the figures below).

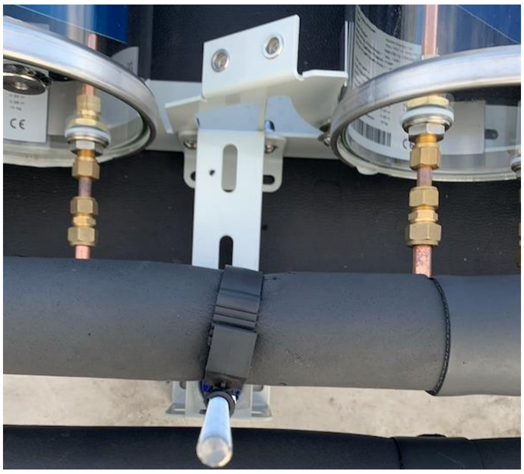


Figure 5 - Manifold Support Bar and Strap

12.10 Other pipework elements on the roof

AAVs (Automatic air vents)
These should be installed both at the end of the Top Manifold and at any other high point on the roof that could be an air trap (see also section 6.6).

Flow setters and Shut-off valves
The connections to the end of rows should use the reverse-return connection method (see section 4) to ensure equal flow rates. Alternatively (to minimise pipe connection lengths), direct connection can be made without reverse-return but including flow setters on each row, to allow the flow rate along each row to be balanced. Flow setters have a visual indicator of flow and a quarter turn adjustment valve (see photo below). The visual flow indication can also be useful during commissioning. If flow setters are not installed it is advisable to include quarter turn shut-off valves on each row of Tubes, to allow each to be isolated if needed during maintenance.

Figure 6 - Example of a Flow Setter with a flow meter

Temperature sensors
These should be included on both flow and return lines, to enable accurate measurement of thermal power generation and control of the pumping system.

They should be located as close to the solar array as possible (at a maximum distance of 3 metres from the first flow and last return manifold). The sensors can either be thermocouples in pockets (e.g. PT1000 type) or be part of a heat meter. With temperature pockets it is important to ensure that they are the correct length, such that they protrude into the flow of the pipe (see photo below). If they are shorter and sit in a stagnant region outside the flow they will not read the temperature accurately.

Figure 7 - Sensor Pocket

Pressure relief valve (PRV)
In cases where there is a long pipe run from the plant room to array, a PRV should also be installed on the pipework close to the array (see also section 6.5 on system pressure management). In this case, the outlet from the PRV should be connected to a downpipe, so that it drains into a safe location if high temperature glycol or steam are released at high pressures.

Thermal Insulation
All the copper pipework should be insulated with high temperature, outdoor rated insulation, including the 8-10 mm connections, the manifolds and other pipe runs back to the plant room. However, the pipe insulation around connectors should not be completed or sealed until the system has been filled and leak checked (see section 13). When attaching and sealing insulation with a slit along one side, always try to position the slit at the bottom, so that any gaps in the sealing do not let rain in and if any water does get inside the insulation it drains out again.

12.11 – *VirtuHOT only* – Attaching Reflectors and Front-of-Row Reflector

The Reflectors are first slotted into the vertical slots and then attached to the Side Frames using M8 x 16 mm Socket Cap Screws (see photos below).

Figure 8 - Front and Back of Row Reflector

At the front of each row of Tubes an additional Reflector is attached to the frame vertically, with the angled section upwards. This provides mechanical support to the Reflector at the front. Secure it first to the Side Frames using M8 x 16 mm Socket Cap Screws (see photo below).

Figure 9 - Reflector fitted to support the underside of the End of Row Reflector

Next, it should be securely attached to the front Reflector in 2 places (1/3 and 2/3 along the length), by drilling 2 holes and fixing each with an M8 nut and bolt (see photos below).


Figure 10 - m8 Nut and Bolt used to fix both Reflectors to each other

12.12 Equipotential Bonding of manifolds

10 mm^2 earth cable should be used to connect the Manifolds to a protective earth. The Side Frame can also be earthed, but this is not usually required. A connection to the Frame is made with an M5 self-tapping screw and the recommended location is near the ends of the Frame. To earth the manifolds, earth clamps should be fitted to both of them and an earthing cable used to connect these also to the protective earth (see photo below).

Figure 11 – Earthing/Bonding

12.13 Installation sign-off checklist – Page 1 (of 1)

Action completed	Yes/No	Comment
Gaskets used on pipework fittings are solar rated (high temperature, glycol).		
Insulation used on pipework is outdoor rated (UV resistant, waterproof).		
AAV's are installed on array top manifolds and in plant room.		
Temperature sensor pockets are right length for sensors to be within flow.		
Front-of-row Reflectors are attached.		
Manifolds are earth bonded		
Removable film has been left on glass tubes (until commissioning complete).		

Question	Answer
What is exact orientation of array? (° from South)	
How many Virtu tubes were damaged on arrival and not used?	
Where are PRV's installed and what is their pressure rating?	
Are flow setters or shut-off valves installed on the array?	
Other comments/notes?	

Sign off to show that installation has been completed:

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Name of installer Signature Date

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Name of system owner Signature Date

13. System filling and commissioning

Once the array and plant room installation have been completed the system can be filled. The pipe insulation around connectors should not be sealed until this has been carried out and the system has been confirmed to be leak tight.

The heat transfer fluid can either be glycol or (in frost-free climates) with de-mineralized water with a corrosion inhibitor additive. See section 6.8 for notes on the fluid selection.

Filling is most easily carried out using a Filling Station, but a Top-up (Pressurisation) Station can also be used (as shown in photos below).

Filling station (Resol SBS2000) Top-up station (BOSS AX-E)

The Filling Station is the best option for filling and cleaning, as the pump power is high enough to rapidly circulate the fluid and therefore remove the air quickly. A Top-up Station is less efficient at removing the air, but can be used to fill and then the main system pump can be used to circulate. The other benefit of a Top-up Station is that it can be used to maintain the pressure at a constant level. This is helpful in reducing maintenance – without this, the pressure needs to be monitored and a manual top up carried out if/when pressure falls below a setpoint (see also section 15). Without a top-up station there is a risk that manual top-up is done using mains water (when pressure drops), which will lead over time to dilution of the glycol and risk frost damage or corrosion (as the corrosion inhibitor becomes diluted).

13.1 Cleaning the pipework and filling system

It is important to clean the pipework before filling, especially when the system will be filled with glycol. This is because residue in the pipes can promote bacterial growth (especially when the system is run in the temperature range 30-50ºC), which will degrade the glycol and reduce its lifetime. A 2 stage clean is recommended, the first a chemical clean that removes metal residues and grease and the second a biocide, to sterilise the pipework. For example, Kilfrost make 2 cleaning fluids: a chemical clean called SF10 and a biocide called SF20. To clean the system with these, the following sequence is recommended:

1. Before filling the system with water it is important to confirm the system is leak tight, to avoid flooding risks. If possible, connect a compressor or compressed air line to a point on the system and pressurise the system with air. Pressurise to 1 bar and then valve off, to confirm the system holds this pressure (for 60 seconds). Then repeat at 3 bar. If there is no compressed air on site, confirm with the pipework installer and check visually that all fittings have been connected and tightened.
2. Connect a hose from the Filling Station pump outlet to a port in front of the Pump Station (the outlet) and a second return line hose from just behind the Pump Station into the reservoir of the Filling station. Close the manual valve inside the Pump Station (between the 2 connections), so that the Filling Station is now acting in place of the Pump Station.
3. Add SF10 to water in the correct concentration in the Filling Station reservoir and then turn on the Filling Station pump to start to fill the system with SF10 solution. As the level in the reservoir falls, keep adding more water and SF10 (at the correct concentration), to maintain the reservoir level, until the system is completely filled.
4. Once filled allow the system pressure to rise to between 1-2 bar (this can be controlled using the Filling station pump power and valves and checking a manual pressure gauge at the filling point), and continue to circulate the SF10 solution in the system.
5. Visually check for any leaks and fix any leaking fittings.
6. Ensure the AAV manual valves are open to remove any air bubbles and actuate all valves on the system to release any trapped air and to circulate the SF10 solution to all parts of the pipework.
7. Check for leaks again and then circulate the SF10 solution to clean the system for at least 2 hours (or overnight – see also section 13.2 below)
8. Flush the system with clean water to flush out the SF10 solution. This can be done by (i) removing the return line hose from the Filling Station reservoir and putting it to a drain and (ii) using a third hose to fill the Filling Station reservoir with new clean water from a mains tap. The system should be flushed out with twice the system volume (so if the system volume is 100 litres it should be flushed with 200 litres).
9. Next, fill with SF20 solution – to do this, replace the return line hose into the Filling Station reservoir, so that the water is circulating continuously and then slowly add SF20 to the reservoir, to the correct concentration (based on total system volume)
10. Circulate the SF20 solution, adjust the pressure to 1-2 bar if needed and actuate all valves to circulate SF20 to all parts of the system pipework. Check AAV valves for any trapped air.
11. Circulate SF20 to clean system for at least 2 hours (or overnight – see section 13.2 below on pressure drop test)
12. Flush out the system with clean water using the method in step 7.
13. Fill system with glycol solution. This can be done by (i) removing the return line hose from the Filling Station reservoir and putting it to drain, (ii) letting the reservoir drain of water almost to the bottom, (iii) filling the reservoir with the glycol mixture, so the system starts filling with glycol, (iv) glycol is observed to come through the return line hose (colour change), then put return line hose back into the reservoir.

13.2 Pressure drop test

During the sequence described in 13.1 above, preferably quite early on (to give time to fix leaks and re-test), it is important to carry out a pressure drop test, to confirm the system is really leak tight. This is done over-night, so can be included at either step 6 or 10 above, depending on timing. **Note however, that if there is a risk of freezing temperatures over night it should not be done with just water (or the SF10 or SF20 cleaning solutions) in the system, but instead wait until the system has been filled with glycol. If the system is filled with water and allowed to freeze, substantial damage may occur to the Virtu tubes and pipework and this will not be covered by the product warranty.**

The procedure for measuring pressure drop is:

1. Turn off Filling Station pump, close all AAV manual valves and close a valve at the return line hose connection.
2. Turn on the Filling Station pump and monitor the system pressure rise to 3 bar (it will rise quickly with the return line valved off). Once 3 bar is reached close the valve at the inlet hose too, to keep it at 3 bar and turn off the Filling Station pump. The system should now be stable at 3 bar with no circulation.
3. Leave the system overnight and then check the pressure again. If it has fallen by more than 0.2 bar in 12 hours check carefully for leaks.
4. Once complete, reduce pressure back to 1-2 bar, open AAV isolation valves and continuing circulating the cleaning fluid (at step 6 or 10 in section 13.1 above).
5. This pressure drop procedure can be repeated multiple times – initially air bubbles in the system can cause a small pressure drop and if repeated later this effect reduces.

Once the system is leak tested and filled with glycol, the remaining pipe insulation can be fitted and the joins between insulation sealed using adhesive or tape.

Once filling and leak checking is complete, the pressure should be set at the desired operating level (1-2 bar depending on system design and temperature).

Next, check the pressure in the expansion vessel. This should be set to a similar pressure to the desired system pressure (or slightly higher), so that the expansion vessel is 25-50% full (of glycol) in normal operating conditions. Expansion vessels are often received charged to 3 bar, which is usually too high. Let some air out to reduce it to match the desired system pressure (usually 1-2 bar). If the expansion vessel is too low, a foot pump can be used to add air pressure.

Make a final adjustment to the system pressure. Then the Filling Station can be isolated and disconnected. It is important then to open the manual valve in the Pump Station, to allow the Pump station to control the flow around the system.

13.3 Controller set up and commissioning checks

The controller set up and commissioning procedure will depend on the controller type and system design, but the details here are intended to be a useful guide to the main steps.

1. If the system has a PWM Pump (such as a Grundfos UMP3 solar) in the pump station then check the PWM control is wired correctly for the Resol controller. There should be a small leaflet that comes with the pump station. Also check the pump is powered from the correct relay.
2. Check the other Resol connections, including the temperature sensors (S1, S2 etc) and pump and valve controls (R1, R2 etc). Match these up to the system schematic, so that it is clear which sensor and control number relates to which one in the controller. Things to double check:
    a. that the sensors are on the right line e.g. S1 on the line that comes back from the solar array and S2 on the flow line that goes to the solar array (not switched round). Alternatively S2 can be the storage cylinder (if this is specified in the system design)
    b. that the flow goes into and out of the correct port on any cylinder or Thermal Store (usually input port is above output)
    c. that connections to the Heat Exchanger are correct (if there is one in the system) – there are 4 connections and it is easy to have these be connected incorrectly.
3. Switch on the Resol controller and check for error messages. If the controller has already been setup, check the system configuration type and control modes set. If it has not yet been set up, set these up now, using the Resol Deltasol manual.
4. Check the clock is set correctly on the Resol controller.
5. Check the pump is set to the correct PWM curve (leaflet should come with pump station) and confirm that it runs correctly and produces flow in the right direction through the system.
6. Run the pump for 15 minutes to confirm the glycol has fully circulated and any remaining air has been excluded via the AAVs.
7. Check all sensors are reading values in expected ranges for current time and system setup.
8. Check you are happy with how the installer has set up the following and if not, discuss the modes and settings with the installer and/or customer:
    a. Flow turn-on control – there are 4 options:
        i. Delta T between S1 and S2 in combination with pulsed flow using the Tube Collector optional function (e.g. 1 min flow every 4 minutes)
        ii. Light intensity using CS10 light sensor
        iii. Both (i) and (ii) in combination
        iv. 24 hour flow
    b. the heat dump control – typically a 3-way valve is actuated based on S1 being above a maximum value (e.g. 80ºC)

    c. thermal store bypass control – typically a 3-way valve is actuated, either based on S1 being above a certain value or a Delta T comparison of S1 with the Thermal Store temperature.
9. Test the controller is operating in the manner expected by manually changing sensor temperatures to make sure the pump comes on and relays activate. This can be done by removing the sensors from their thermal pockets and putting them into a cup of cold water or hot water. Check the pump operates at the flow rate you are expecting by looking at the manual flow meter on the pump station.
10. If a CS10 light sensor is used, check that the signal is correctly recorded by the Resol controller and that the flow turns on and off in response to the signal. Recommended levels are to turn on flow above 100 W/m2 and use a delay of 30 seconds (for turning flow on or off when light level changes).
11. Turn down the heat dump temperature on the controller and then check the heat dump activates properly when you manually raise the panels sensor temperature.
12. Double check that the 3-way valves operate in the right direction i.e. they bypass when desired (not the wrong way round).
13. After testing the control modes and sensors, make sure that all sensors are put back in the correct sensor pockets and secured in place.
14. Set up the Data logger and check the interface between the Resol controller and the datalogger and confirm that data is being logged as required.
15. Check the data logger is internet connected and set up the Resol vbus website to connect to the controller. Confirm that system values (e.g. temperatures) can be viewed at the Resol vbus website.
16. Put the Resol controller in automatic control and ensure that someone is available on site to keep a close eye on how the system runs for the first few days.

Once commissioning checks are completed, the protective film from the Virtu tubes can be removed, to allow them to start to generate heat. However, it is good practice to just remove the film from some of the tubes in the array and wait until the array has been running successfully in sunny conditions for 48 hours before removing the protective films from the remaining tubes. This will reduce the probability of a stagnation event during the first few days of operation – our experience has shown this first week is the highest risk time for stagnation, as features or settings in the controller or system may not have been correctly adjusted or the system heat demand may not match what was expected. Removing the film from just some tubes is a good way to test out the system while reducing risk of stagnation damage. For example the film could be removed from just the first 5 tubes out of each row of 20-30.

A site visit 1 week after commissioning can be a good time to check system pressure, optimise settings and remove the protective film form the remaining tubes. At this visit the manual valves on the AAVs should also be closed, to avoid the risk of these drying out and letting air back in to the system. Any filters should also be checked and cleaned if necessary.

13.4 Commissioning sign-off checklist – page 1 (of 3)

The Commissioning sign off checklist below must be completed at the time of commissioning. One copy of the checklist should be retained with this manual and one copy must be returned to Naked Energy. **This requirement forms part of the manufacturer warranty.**

Action completed	**Yes/No**	**Comment**
Installation checklist completed and checked (see section 12.17)		
System is leak tight (pressure drop test completed and passed).		
Chemical cleaning was carried out before filling with glycol.		
S1 and S2 sensors are on correct pipes. S1 must be on Hot Flow Pipe (from the Array) located on the roof. S2 must be inside the Cylinder or on Return pipe from Cylinder to Array		
Connections to Cylinder(s) are correct to the Manufacture's drawing (usually flow direction is in at the top)		
Connections to Heat Exchanger are correct (to system schematic and Manufacturer's instructions).		
3-way valves are correct way round (e.g. to Bypass or Heat Dump).		
Clock on controller is correctly set (and Daylight Saving setting is correct).		
Pump is set to the correct PWM curve in controller (pump set to 'Solar Control')		
Pump speed control tested and correct flow confirmed at max and min settings. Note the maximum speed at 100%.		
Pump relay on/off function tested (in response to temp sensors S1/S2)		
Bypass function tested (3-way valve operates correctly) – only if bypass fitted		
Heat Dump function tested (3-way valve and/or fan operate correctly)		
All temperature sensors have been replaced in correct pockets after testing.		
Data logger is set up and is logging data to vbus site.		
Protective film removed from some (or all) of Virtu tubes.		

13.4 Commissioning sign-off checklist – page 2 (of 3)

Action completed	Yes/No	Comment
Pipe insulation complete, edges sealed		
Expansion vessel pressure checked and adjusted to match desired system pressure.		
AAV manual valves left open and the schedule to close them agreed.		
Any array or system labelling completed (e.g. sensors, 3-way valves).		
System owner (responsible for ongoing operation and maintenance) identified		
Copy of this installation manual left with system owner		
Alarm responses table (section 14.2) discussed with system owner		
Maintenance schedule/tasks (section 15) discussed with system owner		
Emergency shutdown procedure displayed on site		
All documentation to be kept in identified location (e.g. in plant room)		
Follow-up site visit (by commissioning or maintenance engineer) scheduled		

13.4 Commissioning sign-off checklist – page 3 (of 3)

Controller sensor and output list	Location and type of sensor/output
S1	
S2	
S3	
S4	
R1	
R2	
R3	

Mode switch trigger (e.g. bypass)	Temperature setpoint

Question	Answer
What water/glycol pressure has system been tested to?	
Record pressure drop test result (e.g. 3 bar to 2.9 bar after 12 hours)	
What chemical cleaning fluid was used?	
What brand/type of glycol was used, what % mixture and what is its min. and max. temperature rating?	
How is pump on/off controlled (pulse, light sensor, other)?	
Expansion tank volume (litres)	
Minimum system pressure (for alarm)	

Sign off to show that commissioning has been completed:

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Name of commissioning engineer	Signature	Date
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Name of system owner	Signature	Date

14. Controls modes and fault modes

14.1 Controls modes

In a solar thermal system, there is usually a desired demand temperature: the temperature at which heat is delivered to the building or application via a heat exchanger of coil within a thermal store. Even with a pre-heat system, where the solar thermal heat is used to pre-heat the feed to the primary heating system, there is a useful temperature range for this pre-heating.

Based on this target normal operating temperature there are a number of modes that can be defined for the controller:

Mode	Condition
Standby	Pump not running (nightime or cloudy day) or pulsing on and off
Accumulate	Pump running, array heating up, heat exchanger or thermal store bypassed
Normal run	Pump running, heat delivered to building or application via heat exchanger or thermal store
Over-temperature	Pump running, flow bypassed to heat dump (fan coil unit)
Fault	Pump not running, system may be over-heating or have lost pressure

The controller setup is configured around the system elements (how many array circuits, pumps, stores etc) and the desired triggers between the control modes listed above. The approaches to these control modes have already been described in sections 7 and 13.3 above. The primary trigger to switch modes is the temperature of the water coming out of the solar array (S1 – the return line), but a comparison of temperatures (Delta T) between flow and return or between buffer tank and thermal store can also be useful. Time of day and light intensity can also be useful in controlling the switch between Standy and Accumulate.

When setting switching temperatures it is important to allow for some hysteresis between the temperature to switch between 2 modes. For example, if the system is set to switch up from Accumulate to Normal Run at 40°C, it should be set to switch back down to Accumulate at 35°C. This 5°C gap avoids continuous rapid switching and oscillation in the control system.

In some applications, the switching temperatures for the modes will change with season. For example, in autumn/winter/spring thermal energy may be used for heating, but in summer it may be used for solar cooling or stored for use in autumn/winter. It may therefore be useful to document a matrix of modes and setpoints for each season or application mode.

14.2 Fault modes

It is also important to define possible fault scenarios and the appropriate responses. These may trigger maintenance or send an alert message. It is critical to define who should any alarms alerts be sent to and who is responsible for fixing faults, especially out of office hours.

	Failure case	Software action - water flow	Alert	Other action
1	water leak -> loss of pressure, flow	stop pumps	text alert	Cover array with tarpaulins, fix leak, refill
2	pumps fail - no water flow to array		text alert	Cover array with tarpaulins
3	pumps fail on system side - no water flow to heat exchanger	keep array pumps on (max flow)	text alert	Cover array with tarpaulins
4	temperature in array >100°C after pump/power failure	keep pumps off	text alert	Cover array with tarpaulins, wait until temp in array <80°C, then move to Over-temp mode
5	No flow rate recorded by flow meter (but pumps and pressure appear ok)	keep pumps on (normal flow for that state)	text alert	Maintenance to investigate flow meter, valves, pumps: if no flow is real, cover array
6	Error on temp sensor (outside normal range, high noise)	keep pumps on (normal flow for that state)	text alert	Maintenance to investigate
7	Flow rate is variable - not in control	keep pumps on (normal flow for that state)	text alert	Maintenance to investigate
8	Pressure shows gradual decrease to below normal range	keep pumps on (normal flow for that state)	text alert	Maintenance to investigate (filters blocked, leak at array?) - consider manual top up.
9	Pressure gradual increase to outside normal range	keep pumps on (normal flow for that state)	text alert	Maintenance to investigate (filters blocked, PRVs working?) - consider releasing pressure
10	Mains power loss	no flow	text alert	Cover array with tarpaulins
11	System fault or maintenance	keep array pumps on (max flow)	text alert	Cover array with tarpaulins

14.3 Thermal shock

Fault 4 in the above table is worth noting and explaining in more detail. In a stagnation condition, if there has been no water flow for long enough for the temperature to rise about 100°C in the Virtu tubes (approximately 15 minutes in bright sun), then it is preferable not to switch the water flow back on until the tubes have cooled, since putting cold water into the tubes >100°C can result in a thermal shock, which can damage the PV cells and vacuum feedthroughs. It may also result in a pressure burst and degrade the glycol fluid. Alternative approaches to cooling the tubes (with the flow kept off), include covering or shading them (e.g. with a tarpaulin) or waiting for the sun intensity to fall (e.g. in late afternoon). A decision on the best action will depend on consideration of the system condition. For example, if the water in the whole system is 80°C and the Virtu tubes are 100°C there will not be a large thermal shock when turning the water back on, but if this difference is >40°C then it is recommended to keep the flow off until the temperature difference falls.

15.System maintenance schedule

The Virtu array and system should be regularly inspected to ensure no damage has occurred, for example due to severe weather or animal damage, and that the system is running within normal operating parameters.

The system should be maintained and checked for faults on a regular basis. If the controller goes into a fault mode, an automatic alert should be sent to the engineer responsible for system maintenance, who should address the fault issue before any damage can occur to the system. The following is a list of additional annual checks that should be carried out by the local maintenance team:

Annual checks:

1	Cleaning	Clean glass tubes and reflectors
2	Roof	Check any roof fixings are firm and the roof covering is satisfactory by visual inspection.
3	AAVs	Open the manual valves on the Automatic Air Vents and release any air pockets behind them (then close them again)
4	PRVs	Check Pressure Relief Valves are still functional
5	Glycol	Every year, check concentration and pH of glycol. If the system has been topped up with water, it is important to confirm the glycol concentration has not dropped too much (**note: frost protection and corrosion inhibition reduce with increasing dilution**). Every 5 years drain the system, carry out a chemical clean (as detailed in section 13.1) and refill with new glycol solution.

6	Sensors	Check electrical controls and sensors are operating correctly
7	Flow rate	Check flow rate remains at level stated on the commissioning certificate
8	Pump	Check the circulating pump is operating without excessive noise or vibration. Service the pump and motor according to the manufacturer's documentation.
9	3-way valves and heat dump	Check 3-way valves and heat dumps are operational (some components can seize when not used very often)
10	Pipework	Check insulation is firmly in place and not damaged (e.g. by weathering or animals).
11	Check Virtu tubes for damage	If any damage is found contact Naked Energy to discuss if repair or replacement is needed.
12	Labels and documentation	Check all safety and information labels are in place and the plant room documentation pack is up to date.

16. Decommisioning, replacement and recycling

When a VirtuHOT system is being decommissioned, or when a damaged Virtu tube must be removed for replacement, it is important to follow these guidelines:

- Array must be covered and system allowed to cool sufficiently before work commences.
- For system decommissioning the glycol system should be de-pressurised and drained and the glycol mixture disposed of according to local regulations.
- For single tube removal, the manifolds should be isolated using the end of row isolation valves and the compression fittings to the tube can then be removed. If weather conditions are sunny, the other tubes in this row should be covered by a tarpaulin, to prevent over-heating.
- Before removing and arranging for disposal of Virtu tubes the vacuum inside the glass tube should be released. This avoids the risk of breakage while under vacuum, which can result in flying glass fragments. The vacuum can be released by using a screwdriver carefully to lever up the vacuum button valve edge until a hissing sound is heard (see photo below) and holding it in the position until the hissing stops (showing that atmospheric pressure has been reached). **Eye protection should be worn while releasing tube vacuum or when handling tubes under vacuum.**
- Please contact Naked Energy for advice on recycling of VirtuHOT tubes.

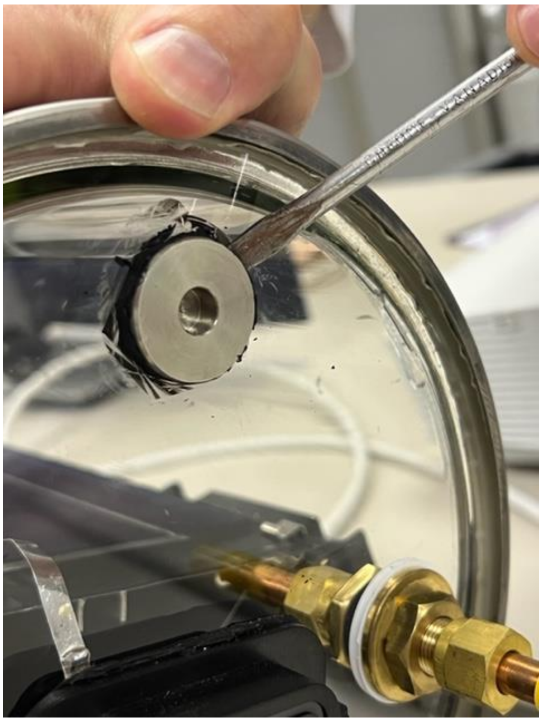
Figure 44 Vacuum Release