Apricus Solar Collector

Information Booklet

Revision 1.3 - January 2008

Contents

1. Apricus Product Overview

1.1. Product Range

Apricus is focused on the design and production of high quality thermal solar collectors and related products. Apricus offers the following key products:
- Evacuated tube heat pipe solar collectors
- Solar controllers
- Pump stations
- Heat dissipators
- Solar Conversion Valves
- Other related components

1.2. Certification

Apricus's manufacturing plant is operated in line with ISO9001:2000 requirements, meaning that we implement comprehensive quality control and system management processes.

Apricus solar collectors are quality and performance certified by a number of international organizations, namely SRCC, FSEC, Solarkeymark and Australian Standards.

To view certificates and test reports, please visit the Apricus website:

http://www.apricus.com/html/solar_collector_certification.htm

2. General Specifications

2.1. Overview

The Apricus solar collector is a thermal solar collector that uses twin glass evacuated tubes as the solar absorber. Copper heat pipes are used to transfer the heat from within the evacuated tube to a heat transfer manifold, with metal fins positioned within the evacuated tube to aid heat transfer and hold the heat pipes firmly in place.

The heat transfer manifold consists of a copper header pipe through which heat transfer liquid (water or water-glycol mix) is circulated. The header is designed with dry contact ports into which the heat pipes plug, allowing efficient heat transfer. There is no water inside the evacuated tubes, and no direct contact between the heat pipes and the heat transfer liquid, as such the system is suitable for mains pressure.

The manifold and tubes are attached to a stainless steel mounting frame, which can be mounted directly on a roof of suitable pitch. Frame kits are also available which allow mounting on flat roofs, walls or low-pitched roofs. By using commercially available frame kits, pole mounting is also possible.

The solar collector has been designed to be suitable for a wide range of system configurations including open loop, closed loop, drainback and even thermosiphon when coupled with a suitable tank. Collectors may be installed in banks of up to 5 collectors in series (150 tubes maximum) and unlimited parallel-connected banks. Apricus solar collectors can be used for both domestic and commercial applications.

Apricus solar collectors have obtained key international product certifications, such as Solarkeymark in Europe, SRCC in the US, and AS2712 in Australia/NZ.

2.2. Basic Collector Data

Collector Size	10 tubes	20 tubes	22 tubes	30 tubes
Overall Length[1]	1980mm / 80”			
Overall Height[2]	156mm / 6.14”			
Overall Width[3]	796mm / 31.3”	1496mm / 58.8”	1636mm / 64.4”	2196mm / 86.4”
Absorber Area[4]	0.8m^2 / 8.6ft^2	1.6m^2 / 17.2ft^2	1.76m^2 / 18.9ft^2	2.4m^2 / 25.8ft^2
Aperture Area[5]	0.94m^2 / 10.1ft^2	1.88m^2 / 20.2ft^2	2.07m^2 / 22.3ft^2	2.82m^2 / 30.3ft^2
Gross Area	1.57m^2 / 16.95ft^2	2.96m^2 / 31.8ft^2	3.24m^2 / 34.8ft^2	4.35m^2 / 46.8ft^2
Gross Dry Weight	34.8kg / 76.5lb	63.5kg / 139.7lb	71.3kg / 156.8lb	94.8kg / 208.5lb
Fluid Capacity	290ml / 9.8floz	520ml / 17.58floz	550ml / 18.6floz	710ml / 24floz

1. Length of frame front track;
2. Height of frame front track + manifold;
3. Width of manifold (not including inlet/outlet ports);
4. Absorber = Outside diameter of inner tube x exposed tube length;
5. Aperture = Inner diameter of outer glass tube x exposed tube length

2.3. Component Specifications

Copper Header

Material	>99.93% Copper Sn<0.012%, Zn<0.04%, Pb<0.003%, Fe<0.004%, Ni<0.003%, As<0.002%, S<0.003%, Bi<0.001%, Sb<0.002%
Length (overall length)	L = (X-1) x 70 + 240mm (X=No. tubes) L = (X-1) x 2.759” + 9.45”
Header Pipe Dimensions	∅18mm OD x 1.2mm ∅0.7” OD x 0.047” (>M grade copper pipe)
Brazing Rod Materials	45% Ag, 30% Cu, 25% Zn (BAg45CuZn) & 93% Cu, 7% P (BCu93P)
Inlet & Outlet	∅22mm OD x 1mm ∅0.866” OD x 0.039” (Attachment by supplied brass fittings or soldered/sweated)
Temperature Sensor Port	∅10 OD x 1.0mm ∅0.39”OD x 0.039”
Recommended Flow Rate	0.1L/tube/min (10tube = 1 L/min) 0.026G/tube/min (10tube = 0.26G/min)
Max Flow Rate	15L/min / 3.9G/min regardless of collector size.
Max Operating Pressure Rating	800kPa / 116psi (850kPa / 123psi PRV acceptable)

Manifold Casing & Insulation

Manifold Length	L= (X-1) x 70mm + 160mm (X=No. tubes) L = (X-1) x 2.759” + 6.3”
Height	130mm / 5.15”
Width	140mm / 5.512”
Tube Spacing	70mm / 2.759”
Manifold Material	0.8mm / 0.03” Aluminium (Grade H16) Matte Black Backed Enamel Finish
Glass Wool Insulation	(~70kg/m^3 / 1.33lb/ft^3) K = 0.043W/mK R = 1.16K.m^2/W or 6.6ft^2.^{o}F.h/Btu

Frame

Material	1.5mm / 0.059” thick 439 Stainless Steel
SS Tube Clips	301 Stainless Steel
Bolts, Washers and Nuts	304 Stainless Steel & 3A21 Aluminium

Evacuated Tubes (Solar absorber)

Tube Length	1800mm / 70.8” (Actual length to tip = 1810-1830mm / 71.25”-72”)
Outer Tube Dimensions	∅58mm x 1.8mm / ∅2.28” x 0.07”
Inner Tube Dimensions	∅47mm x 1.8mm / ∅1.85” x 0.07”
Weight	2kg / 4.4lb
Glass Material	Borosilicate Glass 3.3
Absorber Material	Graded-index coating Al-N on Al on glass
Thermal Expansion	$3.3x10^{-6}$ ^oC
Absorptance (α)	>92% (AM1.5)
Emittance (ε)	<8% (80^{o}C)
Vacuum	P<$5x10^{-3}$ Pa
Stagnation Temperature	>200^{o}C >395^{o}F
Heat Loss	<0.8W/ (m^2 ^{o}C)
Maximum Strength	0.8Mpa 120psi
Absorber Area per Tube **(for standard performance calculations)**	0.08m^2 0.86ft^2
Heat Transfer Fins **(inserted into evacuated tube)**	0.2mm / 0.0078” thick Aluminum Fins & 0.2mm / 0.0078” thick Zinc plated iron clips

Heat Pipes

Length	1800mm 70.8”
Material	∅8mm OD x 0.7mm ∅0.314” OD x 0.027” Oxygen Free Copper (TU1) Cu+Ag> 99.99% (O_2 <16ppm)
Condenser Dimensions	∅20mm OD x 30mm ∅0.78” OD x 1.18”
Heat Transfer Liquid	Purified Water (Non Toxic)
Maximum Working Temperature	300^{o}C 577^{o}F
Startup Temperature	<30^{o}C <86^{o}F
Vacuum	~P<$5x10^{-3}$ Pa
Vertical Installation Angle	20-70^o
Spring Plate	0.8mm / 0.03” Aluminium (Grade 3A21)
Spring	Zinc galvanized High Tensile Steel
Washer	1.5mm / 0.05” Aluminium (Grade 3A21)

Rubber Components

Material	HTV Silicone Rubber (UV stablised)
Density	1.15 g/cm^3 +/- 0.05
Durometer Hardness (Shore A)	50-70 (depends on component)
Elongation	320%
Rebound	54%
Maximum Working Temperature	300^{o}C 577^{o}F
Tensile Strength	6.4 Mpa
Tear Strength	12.5 KNM

2.4. Performance

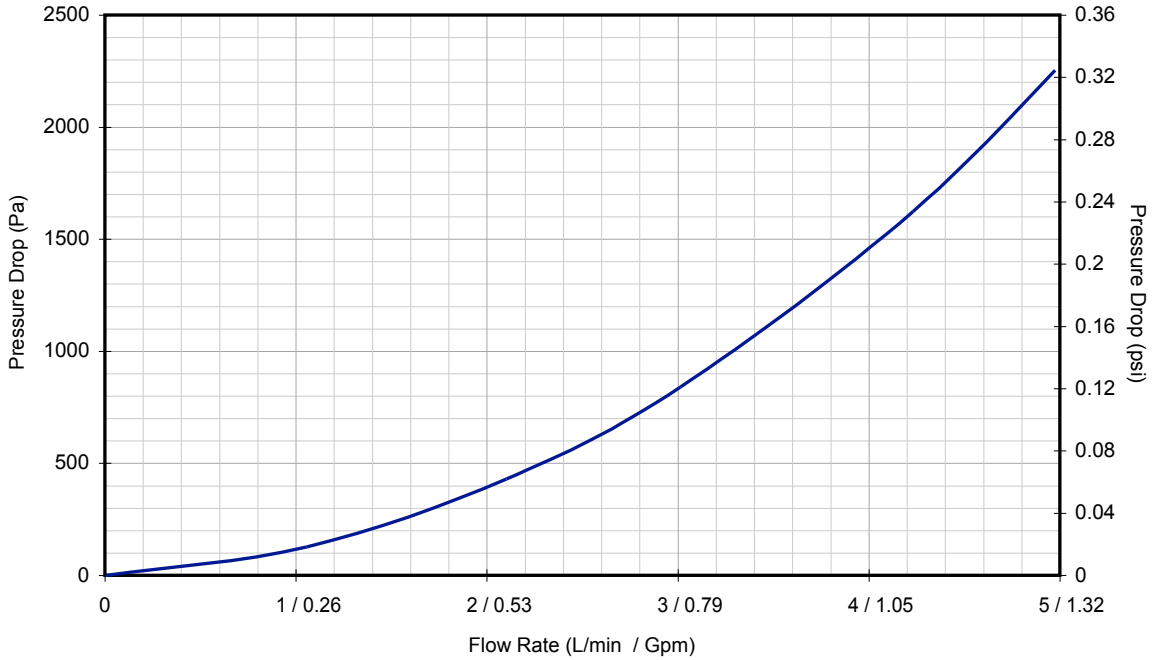
Stagnation	245^{o}C, when G = 1000W/m^2, Ambient Temp =30^{o}C 477^{o}F, when G = 317Btu/ft^2 , Ambient Temp = 86^{o}F									
Efficiency*	ηo (-) = 0.656, a1 (W/m^{2}K) = 1.4, a2 (W/m^{2}K^2) = 0.007 Based on aperture area.									
IAM	0^o	10 ^{o}	20 ^{o}	30 ^{o}	40 ^{o}	50 ^{o}	60 ^{o}	70 ^{o}	80 ^{o}	90 ^{o}
Kθ (longitudinal)						0.93				
Kθ (transversal)	1.0	1.02	1.08	1.18	1.37	1.4	1.34	1.24	0.95	0.0

* Based on independent test reports and internal performance verification testing.

2.5. Pressure Drop

For more accurate calculation of pressure drop, please refer to Apricus document:
AS-1.2.7.1-AP-Pressure-Drop-Calculation-Model.xls

Apricus 30 tube Collector Pressure Drop



2.6. Embedded Carbon Emissions

The follow table provided approximate energy usage and resultant carbon emission involved in the production of the various components of the solar collector, therefore provides a total embedded carbon value.

Material	Weight (kg)	Raw Material Energy Usage	Man. Factor*	Energy Usage (kWh/kg)	Total Energy Usage kWh	Total CO_2 (kg)**
439 Stainless Steel	8.1	0.98 kgC/kg	2	6.44	52.2	52.2
Aluminium	2.6	15 kWh/kg	1.2	18	46.8	46.8
Copper	11.8	1.123 kgC/kg	2	7.78	91.8	91.8
Glass	65	0.257 kgC/kg	1.2	1.01	65.7	65.7
Silicone Rubber	2	1.2 kgC/kg	2	7.89	15.8	15.8
Cardboard Packing	18.5	1.57 kgC/kg	1.2	6.19	114.5	114.5
				TOTAL	**386.7**	**386.7**

* Factor to consider additional energy used during manufacturing of final product.
** Based on 1kg of CO2 per kWh of energy used.

Approximate values for each model size		
Model	kg of CO_2	lb of CO_2
AP-10	139	306
AP-20	258	567
AP-22	290	638
AP-30	387	851

"Payback" time based on average insolation value of 4kWh/m2/day and solar conversion of 65% = 62 days

3. Frame Options

Apricus solar collectors are supplied with a standard frame, which is suitable for direct flush mounting on a suitably pitched roof. For other surfaces or roof pitches, frame kits are available which add to the standard frame to form the complete assembly.

3.1. Frame Kit Part Numbers

Part Name	Description
FR-XX-STANDARD*	Standard Frame Kit
FR-XX-LOW- **	Low Angle Frame Kit
FR-XX-MID-**	Mid Angle Frame Kit
FR-XX-HIGH-**	High Angle Frame Kit
FR-XX-FIXED-AA	Fixed Angle Frame Kit
FR-FTRACK	Front Track (C channel track that runs beneath manifold & tubes)
FR-HBRACE	Horizontal Brace that runs across top of Front Tracks
FR-BTRACK-XX	Bottom Track (used at base of standard frame for tube attachment)
FR-NLOCK	Nut Lock (locks nuts in place inside the frame components)
FR-DBRACE	Diagonal Brace (used for high and mid angle frames)
FR-APLATE-M	Attachment Plate (attaches manifold to frame)
FR-APLATE-B	Attachment Plate (attaches bottom track to frame)
FR-TRLEG	Top Rear Leg (used for high and mid angle frames)
FR-BTLEG	Bottom Rear Leg (used for high angle frame)
FR-SRLEG	Short Rear Leg (used for low angle frame and DEMO collector)
FR-RTRACK	Roof Track (used for low, mid or high angle frames with roof track option)
FR-RXB-HIGH-XX	Rear X Brace for Mid or High angle frame kits (they are the same)
FR-RXB-LOW-XX	Rear X Brace for Low angle frame kits
FR-RFOOT	Round Foot
FR-RCON	Rear connector for roof track
FR-FCON	Front connector for roof track
FR-TCLIP	Tube Clip (secures tubes to bottom track)
FR-RTCAP	Rubber Tube Cap
FR-RFCOVER	Round Foot Rubber Cover
FR-60-RASTRAP	60cm / 2' Roof Attachment Strap (supplied with bolt assembly)
FR-100-RASTRAP	100cm / 3' Roof Attachment Strap (supplied with bolt assembly)
FR-SRPAD	Standard Rubber Frame Pad (for corrugated iron roof)
FR-TRPAD	Extra Thickness Rubber Frame Pad (for asphalt roofs)
FR-SPAN-12/14	12/14mm spanner/wrench used for tightening M8 bolts
FR-BOLT-M8-20	8mm diameter x 20mm long Bolt
FR-BOLT-M8-40	8mm diameter x 40mm long Bolt
FR-BOLT-M8-45	8mm diameter x 45mm long Bolt
FR-BOLT-M8-50	8mm diameter x 50mm long Bolt
FR-WASH-B	22mm OD washer for use with M8 bolts
FR-WASH-S	16mm OD washer for use with M8 bolts
FR-SWASH	Spring washer for use with M8 nuts

Key: XX represents collector size, AA represents fixed frame angle for custom ordered frames
*This is supplied standard with all collectors.
** Either –RFOOT or -RTRACK frame options are available. See section 3.2 for more information.

3.2. Choosing Frame Kits

Location	Frame Type
Suitably Pitched Roof	FR-XX-STANDARD
Insufficient Pitch Roof	FR-XX-LOW- or FR-XX-MID-*
Flat Roof/Ground	FR-XX-HIGH-*
Wall	FR-XX-LOW-, FR-XX-MID- or FR-XX-HIGH-*

* For Low, Mid and High angle frame kits there is the option of Round Feet or Roof Tracks. Roof Tracks may be preferred when installing on a corrugated iron or asphalt shingle roof, as they provide the same C-channel as the standard frame. Refer to frame diagrams for more details.

3.3. Choosing Attachment Accessories

Roof Surface	Part Number
Tiled	FR-60-RASTRAP or FR-100-RASTRAP*
Asphalt Shingle	FR-RFOOT with FR-RFCOVER**
	FR-TRPAD*
Concrete	FR-RFOOT
Corrugated Iron	FR-SRPAD*
Wall	FR-SRPAD* or FR-RFOOT with FR-RFCOVER**

* Can only be used with Standard Frame, or Low/Mid/High Angle Frame Kit using Roof Track.
** The Round Foot Cover is used to avoid direct metal to metal contact when galvanic reaction is an issue, or to prevent the hot metal (in sunny weather) from melting the roof surface (such as asphalt singles).

3.4. Important Frame Notes

a) The frame is stainless steel, and so no contact with zinc galvanised metal should be allowed, as galvanic corrosion of the zinc coating will result. When using the frame on a zinc galvanised iron roof, use rubber frame pads (Part # FR-SRPAD or FR-TRPAD).

b) Ensure that the frame is attached to the structure using 304 or 316 stainless steel bolts. If the roof is galvanized iron, make sure there is no direct contact between the two metals.

c) Ensure the structure to which the frame is mounted is secure, able to withstand the forces that may result during high winds. Refer to local building codes.

d) Do not mount the collector above an area where people may walk (ie. for a wall mount), as in the event storm damage the collector broken glass may be scattered on the ground.

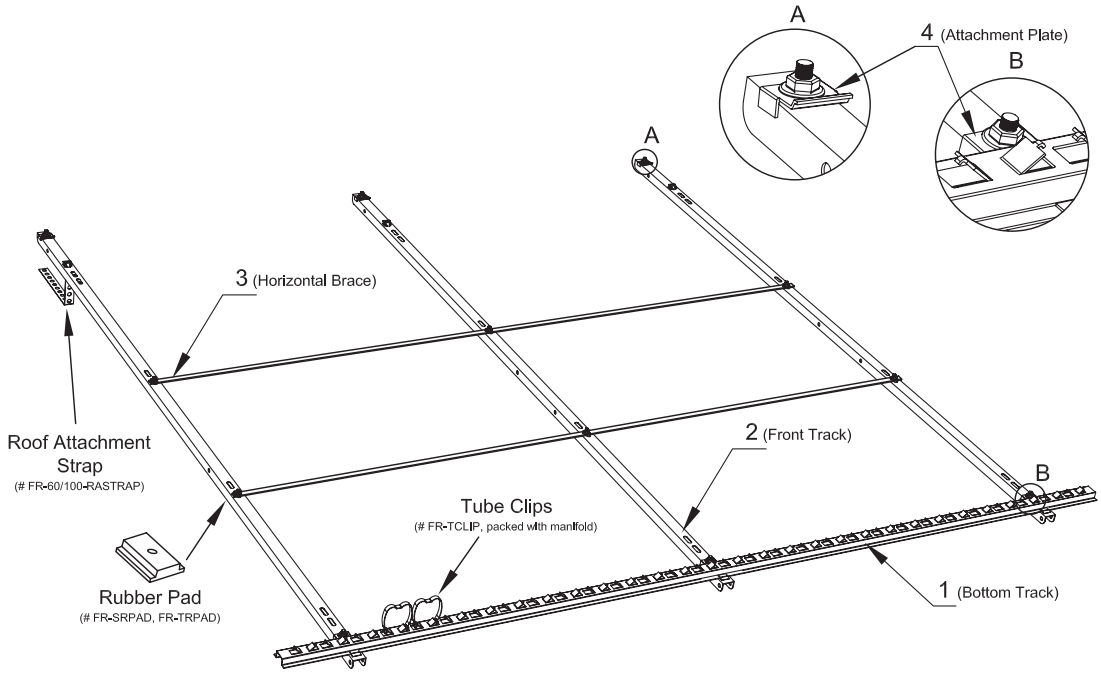
e) Ensure any roof penetrations are water-proof using UV stabilized material, such as rubber roof flashings, silicone sealant or similar.

3.5. Standard Frame

Apricus Solar Collector Standard Frame Kit

Part #: FR-XX-STANDARD

This frame is suitable for flush installation on a pitched roof. If installing on a low pitched roof, or flat roof, an additional frame kit is required which will complement the components already contained in this standard frame kit.



Roof Attachment Options (Components Supplied Seperately)
Tiled Roof - *Roof Attachment Straps*
Corrugated Iron Roof - *Standard Rubber Pads*
Asphalt Shingle Roof - *Extra Thick Rubber Pads*
or
Low, Mid, High or Fixed Angle Frame Kit

SAFETY CONSIDERATIONS
- Wear gloves when handling frame components
- If installing on corrugated iron roofs, always use rubber pads, thus preventing direct contact between galvanised iron and stainless steel frame.
- Ensure roof attachment points are structurally sound
- Follow relevant safety regulations regarding working on roofs

Frame Packing List

Part #	Component Quantities	
	10 & 20 Tube	22 & 30 Tube
1. FR-BTRACK-XX	1	1
2. FR-FTRACK-XX	2	3
3. FR-HBRACE	2	2
4. FR-APLATE	4	6
5. FR-BOLT-M8x20	*8*	*12*
6. FR-NUT-M8	*8*	*12*
7. FR-WASH-B	*4*	*6*
8.FR-SWASH	*8*	*12*
9. FR-WASH-S	*4*	*6*
10. FR-NLOCK	*8*	*12*

Nuts and bolts are already attached to the appropriate components.

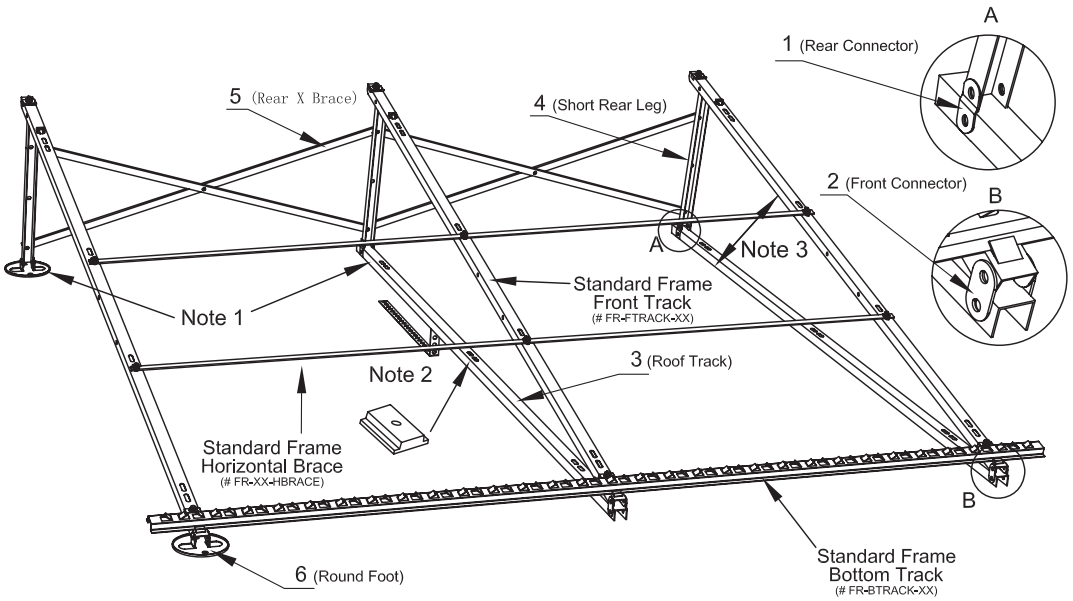
Apricus Solar Co., Ltd Doc: AS-8.1.1

3.6. Low Angle Frame

Apricus Solar Collector Low Angle Frame Kit

Part #: FR-XX-LOW-RFOOT/RTRACK

The components contained in this package combine with the standard frame to form the complete frame assembly shown below.



Notes:
1. There are two mounting options, ROUND FEET or ROOF TRACKS.
2. When using the Roof Tracks, attachment to roof may be via roof attachment straps (# FR-60/100-RASTRAP) or rubber pads (# FR-SRPAD, FR-TRPAD) depending on roof surface.
3. ROUND FEET provide adjustable angle of 11-13deg. ROOF TRACKS provide a set angle of 12deg.

Nuts and bolts are already attached to the appropriate components.

SAFETY CONSIDERATIONS

- Wear gloves when handling frame components
- If installing on galvanised iron roofs, always use rubber pads or rubber feet covers to preventing direct contact between galvanised iron and stainless steel frame.
- Ensure roof attachment points are structurally sound
- Follow relevant safety regulations regarding working on roofs

Frame Packing List

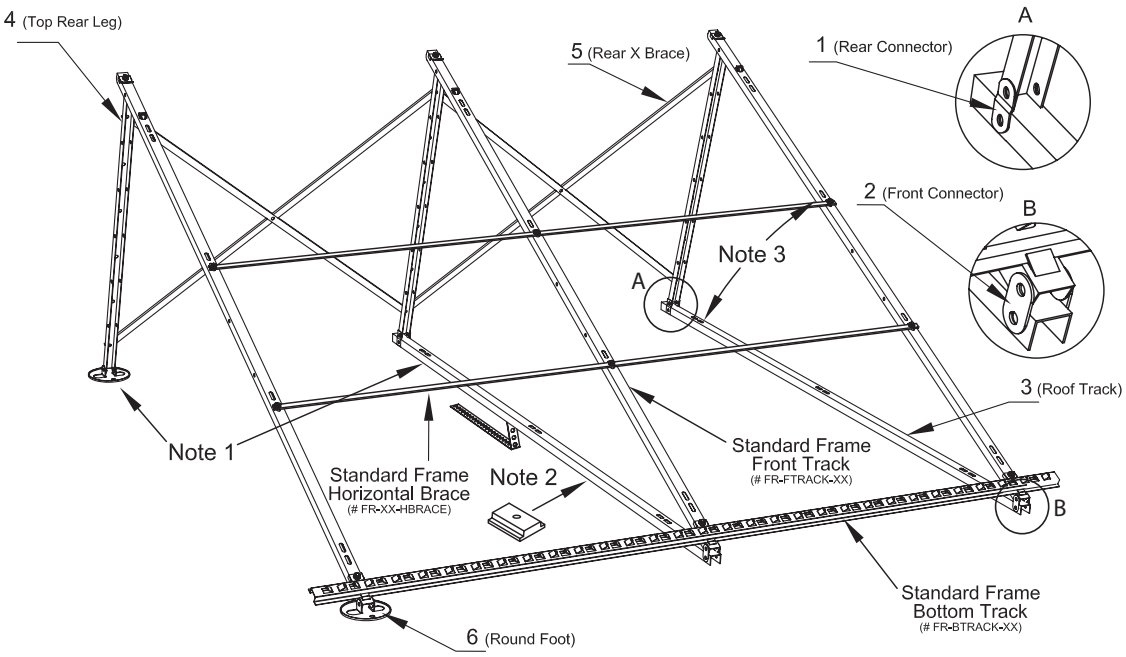
Part #	Component Quantities			
	10 & 20 Tube		22 & 30 Tube	
	FEET	R.TRACK	FEET	R.TRACK
1. FR-RCON	4		6	
2. FR-FCON	4		6	
3. FR-RTRACK	-	2	-	3
4. FR-SRLEG	2		3	
5. FR-RXB-MID-XX	2		4	
6. FR-RFOOT	4	-	6	-
7. FR-BOLT-M8x50	6	10	9	15
8. FR-BOLT-M8x40	1		4	
9. FR-BOLT-M8x20	4	4	4	4
10. FR-NUT-M8	11	15	17	23
11. FR-SWASH	11	15	17	23
12. FR-WASH-S	17	25	26	38
13. FR-WASH-B	4	-	6	-
14. FR-NLOCK	5	5	8	8
15. FR-SPAN-12/14	1			

3.7. Mid Angle Frame

Apricus Solar Collector Mid Angle Frame Kit

Part #: FR-XX-MID-RFOOT/RTRACK

The components contained in this package combine with the standard frame to form the complete frame assembly shown below.



Notes:
1. There are two mounting options, ROUND FEET or ROOF TRACKS.
2. When using the Roof Tracks, attachment to roof may be via roof attachment straps (# FR-60/100-RASTRAP) or rubber pads (# FR-SRPAD, FR-TRPAD) depending on roof surface.
3. ROUND FEET provide an adjustable angle of 21-28deg. ROOF TRACKS provide a set angle of 27deg.

Nuts and bolts are already attached to the appropriate components.

SAFETY CONSIDERATIONS

- Wear gloves when handling frame components
- Feet must be bolted to ground
- Ensure attachment points are structurally sound
- Follow relevant safety regulations regarding working on roofs

Frame Packing List

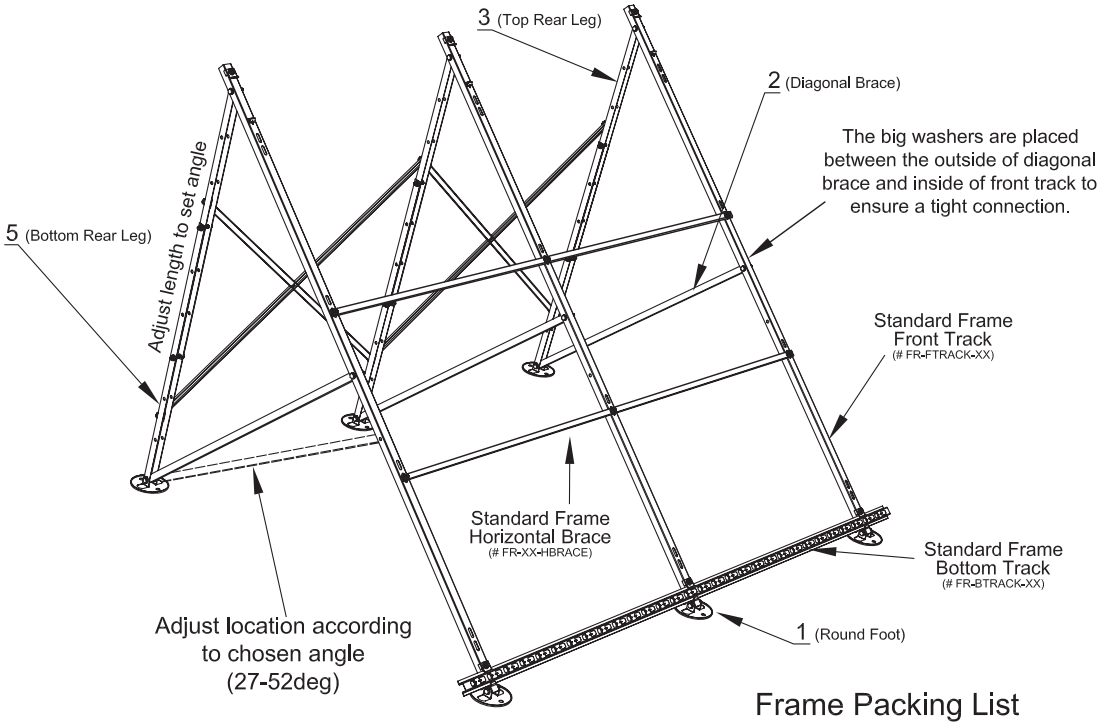
Part #	Component Quantities			
	10 & 20 Tube		22 & 30 Tube	
	FEET	R.TRACK	FEET	R.TRACK
1. FR-RCON	4		6	
2. FR-FCON	4		6	
3. FR-RTRACK	-	2	-	3
4. FR-TRLEG	2		3	
5. FR-RXB-MID-XX	2		4	
6. FR-RFOOT	4	-	6	-
7. FR-BOLT-M8x50	6	10	9	15
8. FR-BOLT-M8x40	1		4	
9. FR-BOLT-M8x20	4	4	4	4
10. FR-NUT-M8	11	15	17	23
11. FR-SWASH	11	15	17	23
12. FR-WASH-S	17	25	26	38
13. FR-WASH-B	4	-	6	-
14. FR-NLOCK	5	5	8	8
15. FR-SPAN-12/14	1			

3.8. High Angle Frame - Round Feet

Apricus Solar Collector High Angle Frame Kit

Part #: FR-XX-HIGH-RFOOT

The components contained in this package combine with the standard frame to form the complete frame assembly shown below.



Frame Packing List

Part #	Component Quantities	
	10 & 20 Tube	22 & 30 Tube
1. FR-RFOOT	4	6
2. FR-DBRACE	2	3
3. FR-TRLEG	2	3
4. FR-RXB-HIGH-XX	2	4
5. FR-BRLEG	2	3
6. FR-BOLT-M8x50	*12*	*18*
7. FR-BOLT-M8x40	*1*	*4*
8. FR-BOLT-M8x20	*4*	*4*
9. FR-NUT-M8	*17*	*26*
10. FR-SWASH	*17*	*26*
11. FR-WASH-S	*29*	*44*
12. FR-WASH-B	*8*	*12*
13. FR-NLOCK	*5*	*8*
14. FR-SPAN-12/14	1	

Nuts and bolts are already attached to the appropriate components

SAFETY CONSIDERATIONS

- Wear gloves when handling frame components
- Feet must be bolted to ground
- Ensure attachment points are structurally sound
- Follow relevant safety regulations regarding working on roofs

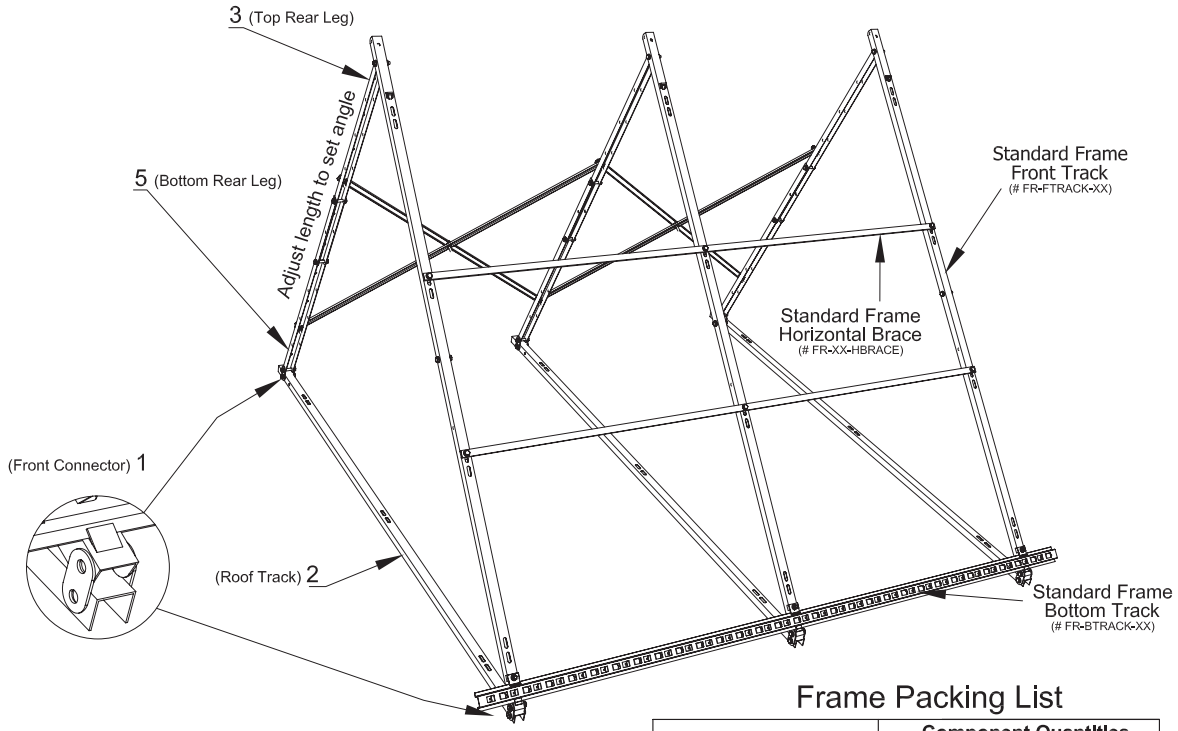
Apricus Solar Co., Ltd Doc: AS-8.1.2

3.9. High Angle Frame - Roof Track

Apricus Solar Collector High Angle Frame Kit

Part #: FR-XX-HIGH-RTRACK

The components contained in this package combine with the standard frame to form the complete frame assembly shown below.



Nuts and bolts are already attached to the appropriate components

Frame Packing List

Part #	Component Quantities	
	10 & 20 Tube	22 & 30 Tube
1. FR-FCON	8	12
2. FR-ROOFTRACK	2	3
3. FR-TRLEG	2	3
4. FR-RXB-HIGH-XX	2	4
5. FR-BRLEG	2	3
6. FR-BOLT-M8x50	*14*	*21*
7. FR-BOLT-M8x40	*1*	*4*
8. FR-BOLT-M8x20	*4*	*4*
9. FR-NUT-M8	*19*	*29*
10. FR-SWASH	*19*	*29*
11. FR-WASH-S	*33*	*50*
12. FR-WASH-B	-	-
13. FR-NLOCK	*5*	*8*
14. FR-SPAN-12/14	1	

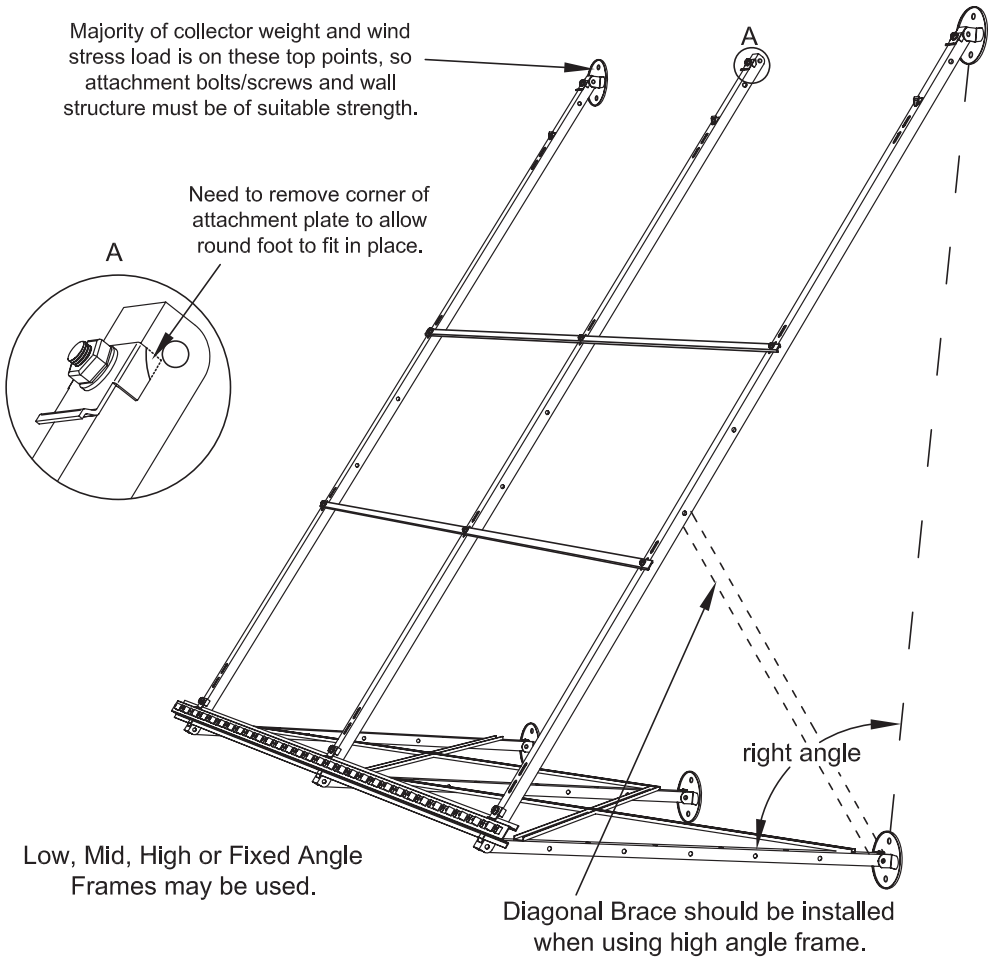
SAFETY CONSIDERATIONS

- Wear gloves when handling frame components
- Feet must be bolted to ground
- Ensure attachment points are structurally sound
- Follow relevant safety regulations regarding working on roofs

Apricus Solar Co., Ltd Doc: AS-8.1.8

3.10. Wall Mounting

Apricus Solar Collector Wall Mounting Diagram



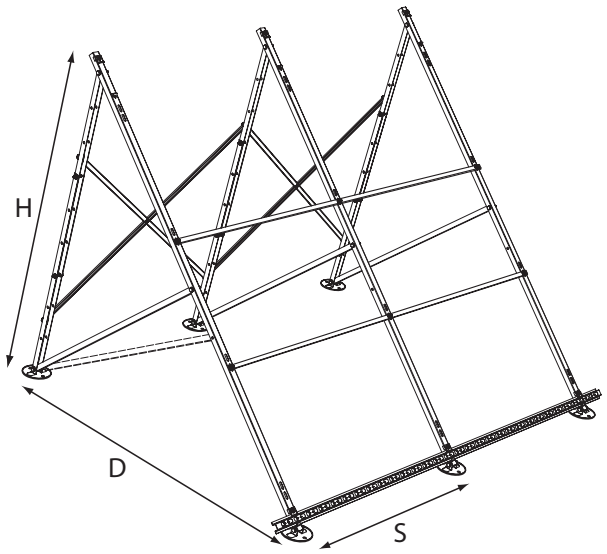
4. Frame Dimensions & Spacing

When using a high angle frame kit on a flat roof (common for commercial applications), the spacing of the frame feet and collectors needs to be known. This depends on the angle at which the collector is installed. The following tables provide this information.
If you wish to know what row spacing should be used to minimize shading, please refer to Apricus document AS-1.2.4.2.

FEET SPACING AND FRAME HEIGHT

Angle	D	H
52º	1406mm / 55.35”	1539mm / 60.6”
45º	1565mm / 61.6”	1389mm / 54.7”
39º	1688mm / 66.45”	1232mm / 48.5”
33º	1792mm / 70.55”	1074mm / 42.3”
28º	1725mm / 67.9” *	936mm / 36.8”

* Using bottom hole on front track for diagonal brace connection.



LATERAL FEET SPACING

Size	S
10 tubes*	490mm / 19.29”
20 tubes*	1190mm / 46.85”
22 tubes	665mm / 26.18”
30 tubes	945mm / 37.2”

* Only 2 front tracks

In all cases the standard location for the front tracks is beneath the second tube from each end (For 22 tube and 30 collectors the third leg is located in a central position). The standard distance between the rear X brace attachment bolts on the rear legs is 600mm (4 holes). Choosing holes further apart, or closer together for the rear X brace attachment points on the rear legs will bring the feet closer together, or splay them further apart, respectively. Starting in 2008, rear X braces come with a series of elongated holes at both ends, allowing the location of the legs to be adjusted slightly to better adapt to roof surfaces.

SPACING OF CONSECUTIVE COLLECTORS
The distance between two consecutive collectors will depend on whether an End or Rear port manifold is being used. In most cases End port manifolds are used for commercial applications, because issues with air-locks are avoided.

The following values are from round foot centre to centre.
REAR = 165mm / 6.5” (5mm / 0.19” gap between manifold ends)
END = 366mm / 14.4” (Using straight 22Cx22C compression fitting)

Please note that a straight connector (no flexibility) may only be used for two collectors in series. More than 2 collectors in series must have flexible connectors.

5. System Sizing Calculations

It is important to have a sound understanding of how to make fast and simple estimations of heat output from a solar collector, and indeed system sizing requirements.

Useful tools for this purpose can be found online at:

http://www.apricus.com/html/solar_collector_size.htm

http://www.apricus.com/html/solar_energy_calculator.htm

Sizing a system can be made very complicated if all factors are considered, however unless it is a commercial system requiring such detailed information, a quick, simple calculation will usually suffice.

5.1. Key Variables

The following factors must be know:

- Average daily hot water usage (tap volume). This can be calculated by checking the flow rate of the shower head, and then estimating the total showering time per day of the household. Additional hot water usage such as for a dishwasher can also be included in the calculation.

- Summer insolation levels. This can be obtained from the Apricus website, NASA website, or other online solar radiation resources. Visit the Apricus site for more information:
  http://www.apricus.com/html/solar_collector_insolation.htm

- Approximate cold water temperature in the summer. If not known use 15^{o}C / 59^{o}F.

5.2. Family Hot Water Usage

There are various methods for calculating hot water usage based on household occupancy. Apricus recommends the following sizing guidelines for most domestic households. Please note this is for a household with optimal (~8L/min / 2.1Gpm) tap flow rates.
100L / 26US Gallons per adult
50L / 13US Gallons per child
Add additional usage for a washing machine (if it uses hot water) and dishwasher.

If the household has high flow shower-heads installed, don't even consider installing solar until that has been remedied!

Therefore for the average family of 4, about 300L / 80Gallons of hot water is used per day. Please note this is based on actual tap flow volume at the target hot water temperature and therefore does not represent the usage of hot water from the tank; that value will be 30-40% lower, depending on the thermostat setting and cold water temperature. Please use Apricus document AS-1.6.6 to calculate cold-hot water ratio.

5.3. Sizing Example

(Metric Units)

> Household using 300L of water per day @ 45°C.
> Summer cold water temperature of 18°C
> Average summer insolation level of 6kWh/m^2/day

Step 1. Determine temperature rise
→ 45 – 18 = 27°C temp rise
Step 2. Determine energy requirement
→ 300L x 27°C = 8,100 kcal (1kcal raises 1L of water by 1°C)
→ 8100 / 859.8 = 9.42kWh (1kWh = 859.8kcal)
Step 3. Determine solar collector output/tube (using average conversion of 60%)
→ 6kWh * 60% conversion = 3.6kWh per m^2 of collector aperture area
→ 3.6kWh * 0.094m^2 absorber area = 0.338 kWh/tube/day
Step 4. Determine tube requirements
→ 9.42kWh ÷ 0.338 = 28 tubes

(US Units)

> Household using 80Gallons of water per day @ 114°F.
> Summer cold water temperature of 65°F
> Average summer insolation level of 1,902Btu/ft^2/day

Step 1. Determine temperature rise
→ 114 – 65 = 49°F temp rise
Step 2. Determine energy requirement
→ 80Gallons = 667.2lb (1 Gallon = 8.34lb of water)
→ 667.2lb x 49°F = 32,692Btu (1Btu raises 1lb of water by 1°F)
Step 3. Determine solar collector output/tube
→ 1902Btu * 60% conversion = 1141Btu per ft^2 of collector aperture area
→ 1141 * 1.01ft^2 absorber area = 1152Btu/tube/day
Step 4. Determine tube requirements
→ 32,692 ÷ 1152 = 28 tubes

So from this simple calculation, it is shown that a 30 tube collector would suit this household perfectly, providing 100% of their hot water needs in the summer, and a percentage throughout the year, dependent on their hot water usage patterns and solar radiation levels.

As a general rule, meeting 100% of hot water needs will provide annual contribution of:
Cold Region = 50-60%
Mild Region = 60-70%
Hot Region = 70-80%

Trying to achieve greater than these levels is only viable if there is a means of using or dissipating the additional heat created in the summer. For example, if the above household installed 2 x 30tube collectors, they could probably achieve an annual average contribution of around 85-90% (100% is impossible), but would have twice as much heat as they need in the summer. There are various methods for dealing with excess heat, namely:

- Using a tank cooling feature on controller, to cool tank at night.
- Install a heat dissipator
- Use excess heat for pool/spa/hot-tub heating
- Install collectors at high angle to minimize summer output

6. Energy Output Calculations

In most cases a rough estimation is all that is needed and therefore simple calculations can be used, but it is also of great benefit to understand performance calculations. The following sections aim to provide a basic overview of calculating collector performance. This is also covered, and with more detail, on the Apricus website.

6.1. Calculating Instantaneous Output

To calculate the output of the solar collector the following factors are required:

> G = Insolation Level (Watts/m^2)
> Temperature differential
    > Tm = Water temperature (being fed to collector)
    > Ta = Ambient temperature
> Collector Performance Variables (based on aperture area)
    > η_0 (y-intercept; Apricus = 0.656)
    > a1 (first coefficient of loss; Apricus = 1.4 W/m^2W)
    > a2 (second coefficient of loss; Apricus = 0.007 W/m^2W^2)
    > X = (Tm-Ta)/G (this is sometimes written as T*m)

The following formula is then used (metric calculations):

Performance = η_0 - a1 * X - a2 * G * $(X)^2$

Example:
→ Solar insolation level of 800Watts/m^2
→ Supply temp to collector from bottom of storage tank of 35^{o}C
→ Ambient temperature of 25^{o}C
→ Direct angle of incidence (ie. Midday)

Therefore: G = 800; X = 0.0125

Plugging those figures into the formula:

→ $0.656 – 1.4 * 0.0125 – 0.007 * 800 * (0.0125)^2$
→ 0.656 – 0.0175 – 0.00175 = 0.637 = 63.7% conversion efficiency

Therefore given 800Watts of solar radiation, the output of the solar collector would be 509.6Watts – this is per m^2 of aperture area. If the calculation was made using collector performance variables based on aperture or gross area, then the output would be based on that sizing.

The absorber area of each Apricus evacuated tube is $0.094m^2$ so a 30tube collector is $2.82m^2$.

The value of 557Watts should therefore be multiplied by 2.82 to obtain the output value for a 30tube collector.

→ 557 x 2.4 = 1437Watts or 1.437kW

6.2. Considering Incidence Angle Modifier (IAM)

The above calculation has considered instantaneous heat output, and at midday when IAM is 1. Given the advantages of the round shaped tubes, and resultant favorable IAM curve, heat output can actually exceed these levels either side of midday.
If you don't know what IAM is then you need to visit the Apricus website and read thoroughly: http://www.apricus.com/html/solar_collector_efficiency_iam.htm

6.3. Calculating Daily or Annual Output

If the calculation of solar collector output over a period of time is required, such as over a day, month or year, a very simple calculation can be made. These calculations are however very general, and are recommended if a fast estimate of heat output is required, such as when sizing a system. For more accurate estimates please use a modeling program such as F-chart or TRNSYS.

The following calculations are completed using metric values, but the same calculations can be completed using Btu/ft^2 for solar radiation and ft^2 for collector aperture area.

6.3.1. Daily Calculation

When considering all factors, the following average solar conversion values can be used for Apricus solar collectors (based on aperture area):

Cold Weather Day = 50%
Mild Weather Day = 55%
Hot Weather Day = 60%

If you want to calculate the heat output for a summer's day, then use the Hot Weather conversion value of 60%. If the daily solar radiation level is 6kWh/m2/day, then the calculation is very straightforward.

→ 6 x 0.60 = 3.6kWh/m2/day (per m2 of solar collector aperture area)
→ 3.6 x 2.82m^2 aperture area (30tubes) = 10kWh

So the total day output for the collector can be expected to reach around 10kWh on a clear sunny day in mid summer, if solar radiation levels are 6kWh/m^2/day.

6.3.2. Annual Calculation

When considering all factors, the following average solar conversion values can be used for Apricus solar collectors:

Cold Region = 50%
Mild Region = 55%
Hot Region = 60%

Using the average annual solar insolation level, a simple calculation can be completed. For a Mild region, the average annual insolation value is around 4.2kWh/m^2/day.

→ 4.2 x 0.55 = 2.31kWh/m^2/day (per m^2 of solar collector aperture area)
→ 2.31 x 2.82m^2 aperture area (30tubes) = 6.51kWh

So the average daily heat output from a 30tube collector is 6.5kWh, which is enough to heat 250L / 66Gallons of water by 24^{o}C / 44^{o}F.

6.4. Units of Measurement for Solar Thermal

Please note that the calculations above have been completed using metric values, primarily because worldwide Watts/m^2 or kWh/m^2/day are the most common units for expressing solar radiation (Eg. NASA website).

The same calculation can be completed using Btu and ^{o}F, however an imperial version of the performance formula is therefore required.

Given the strength of the solar industry in Europe, metric units for solar collector calculations are become the standard even in regions that use imperial measurements. It is therefore highly advisable for solar professionals to have a sound grasp of the metric units and related calculations.

6.5. Apricus sizing and output model

Apricus has developed an excel based sizing program which helps to size a solar system, providing estimated heat output results for the 4 seasons of the year, as well a estimated annual energy savings. The files are available for download from the Dealers Area Site in download section 3.

7. Installation & System Design Considerations

When designing and indeed installing a thermal solar system, many factors must be considered. Please refer to Apricus document AS-1.5.2 for more complete information.

7.1. Use Qualified Engineers

Use qualified and experience engineers/plumbers to complete any custom system designs.

7.2. Use Qualified Installers

In many regions it may be an industry requirement for installers of thermal solar to be certified. Ensure such requirements are met for all installations.

7.3. Do Not Oversize the System

Ideally size the system based on summer solar radiation levels and hot water usage. Sizing for winter will result in excess summer heat, which must be safely used or dissipated. There are various system designs that can allow for an oversized system including using the heat for auxiliary heating (spa/hot-tub/pool), dissipating the heat using a heat dissipator and/or tank cooling function, or minimizing summer output by installing the collector at a high angle.

7.4. Insulation

Copper pipe (as commonly used on the solar loop) is a fantastic natural heat dissipator, and therefore if not well insulated the system performance will be greatly reduced, due to passive heat losses. ALL exposed piping both indoors and outdoors should be heavily insulated, regardless of the climate.

In the case of stagnation, the piping close to the solar collector, in particular on the flow back from collector line, can become very hot, exceeding the limits of most synthetic insulation materials. It is therefore advisable to use a glass wool insulation wrap/pipe on the piping close (within >1m / 3') to the collector(s). Such insulation must be protected from water ingress.

In addition any external insulation material, tapes, wraps, or fittings must be UV stabilized, otherwise they will rapidly deteriorate.

7.5. Installation Location

Installation angle and direction are both important factors which should be considered. As a general rule the installation angle should match the latitude of the region, however this may not be the case if the system design needs to minimize summer output.

The installation angle should be due South/North, depending on which hemisphere you are located. Pointing towards the east or west by up to 10^{o} is acceptable and will have minimal impact on the collector output. Pointing the collector at greater angles towards east or west will change the peak period of heat output to morning or afternoon respectively.

Ensure the collector will not be shaded significantly during the day. Early morning or late afternoon shading is not a major problem as solar radiation levels are low during these periods anyway.

7.6. Safety

Adhere to all relevant safety regulations when completing the installation, in particular health and safety guidelines regarding working on a roof/ladder.

Ensure the collector will not become a hazard in the case of damage. Eg. During a storm if flying debris strikes the collector, tubes may be broken, resulting in broken glass. A consideration of where such glass may fall should be made – if on an area where people are likely to walk, safety measures may need to be employed. Eg. Install a guard below the collector, and/or educate the home owner.

8. Packing & Transport

8.1. Product Packing Standard

Apricus products are packed for sea freight and therefore repacking or additional packing protection may be required if local shipping is planned. Please contact Apricus if you are unsure of how products should be safely packed for such shipping.

8.2. Product Packing Material

Where possible Apricus uses recycled paper sources. Cardboard boxes are generally 70% recycled paper, with 30% new paper required for the outer layer to ensure strength. All paper and plastic used in packing is suitable for recycling.

8.3. Evacuated Tube Shipping

Evacuated tubes are packed in boxes, which are then stood upright on pallets. Standing upright is the safest orientation for the tubes, and where possible should be used for local transport. A single pallet can be loaded into the back of a pickup truck, or indeed a number of tube boxes may be tied together.

It is highly recommended that dealers obtain complete pallets of tubes, as transport is much safer that repacking (as shows to the right).

Lying the tubes down is acceptable for short deliveries to install locations, however care should be taken to ensure the boxes are not able to “bounce” during transport as this could cause damage.

If for reasons of height restrictions in trucks/lorries the tubes need to be shipping lying down, a pallet should be used/made to provide suitable protection.

8.4. Spare Tubes

Always ensure that deliveries include spare tubes. It is not viable to send one or two replacement tubes, so it is a good policy to always include spares. Dealers should always hold more stock of tubes than they have collectors. This will ensure there are spares, and also means that if stock is needed urgently, manifolds and frame kits can be express freighted, which tubes cannot.

8.5. Packing Dimensions and Weights

Item	Dimensions (mm/inches)	Weight	
		kg	lb
Solar Collector Kit Boxes			
APCP-10-KIT	880x240x170 / 34.6x9.45x6.7”	5	11
APCP-20-KIT	1995x240x170 / 78.5x9.45x6.7”	15.5	34.1
APCP-22-KIT	1995x240x170 / 78.5x9.45x6.7”	18.1	39.82
APCP-30-KIT	2300x240x170 / 90.5x9.45x6.7”	22	48.4
Evacuated Tube Boxes			
BOX-ET-HP-10/10	1930x385x210 / 76x15x8.3”	32.5	71.5
BOX-ET-HP-12/10	1930x385x260 / 76x15x10.2”	37.7	82.94
BOX-ET-10	1930x385x210 / 76x15x8.3”	22.2	48.84
Tube Pallets			
PALLET-15X10/10	1140x960x2090 / 44.9x37.8x82.3”	465	1023
PALLET-12X12/10	1140x1030x2090 / 44.9x40.5x82.3”	500	1100

8.6. Packing Details

8.6.1. Solar Collector Kit Boxes Contents

- Solar collector manifold
- 25g tube of heat transfer paste
- Tube clips (for attaching tubes to frame)
- Rubber tube caps
- Standard frame kit

8.6.2. Evacuated Tube & Heat Pipe Boxes

Heat pipe are inserted into the evacuated tubes before packing. There are two types of boxes, 10/10, which have 10 evacuated tubes with heat pipes inserted (BOX-ET-HP-10/10), and 12/10 which have 10 evacuated tubes with heat pipes inserted and 2 spare evacuated tubes (BOX-ET-HP-12/10). The former packing method is the most common, and recommended for most customers.

BOX-ET-HP-10/10 are packed 15 per pallet (5x3)
BOX-ET-HP-12/10 are packed 12 per pallet (4x3).

Spare tubes are provided in each order, and are packed 10 tubes per box with the part name BOX-ET-10. These boxes do not contain any heat pipes. BOX-ET-10 are generally loose packed in the container, but can be packed 15 per pallet if larger quantities are required.

Pallets are made from plastic (starting Dec 2007) and can be be re-used. Paper pallets are not waterproof, so not suitable for storage outside. Wooden pallets are not used due to customs restrictions on such materials.

9. Warranty

Apricus provides a comprehensive warranty policy for the solar collector product. In addition, compensation is provided for warranty claims to contribute to related costs.

For complete warranty and compensation details please refer to the distributor agreement. If you are a dealer, please ask your supplier for compensation details. For warranty details only, refer to Apricus document AS-1.4.1.

10. Disclaimer

Apricus Solar Co., Ltd withholds the right to change dimensions and the characteristics of the product without any forewarning, and rejects any kind of responsibility for misprints.

This booklet is only a guide and as such Apricus Solar Co., Ltd will not be held responsible for any damage to person or property that results during the installation or subsequent use of Apricus products and related system components.

In all cases a thorough understanding of local regulations, laws and common practices must be made and adherence to such ensured, before commencing the design or installation of any system incorporating Apricus products.

www.apricus.com

For more information on the Apricus solar collector please visit the Apricus website, or if you are a Distributor or Dealer please check the Downloads section of the Dealer's Area site.