SOLAR COLLECTORS

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AUSTRIA
Working temperature of different types of solar thermal collectors

Source: ETP RHC, Strategic Research Priorities, 2013
# Types of Collectors

<table>
<thead>
<tr>
<th>Principle</th>
<th><strong>( \eta_0 )</strong></th>
<th><strong>U [W/m(^2) K]</strong></th>
<th>Collector Working Temp.</th>
<th>Application Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple absorber</td>
<td>0.90</td>
<td>20</td>
<td>15 – 30 °C</td>
<td>Swimming pool</td>
</tr>
<tr>
<td>Simple flat-plate collector with glass cover (FP)</td>
<td>0.80</td>
<td>4</td>
<td>30 – 80 °C</td>
<td>Hot water</td>
</tr>
<tr>
<td>FP with selective surface (SS)</td>
<td>0.80</td>
<td>3</td>
<td>40 – 90 °C</td>
<td>Hot water, Space heating</td>
</tr>
<tr>
<td>FP with double anti-reflective coated glazing and gas filling</td>
<td>0.80</td>
<td>2.5</td>
<td>50 – 100 °C</td>
<td>Hot water, Space heating, Cooling</td>
</tr>
<tr>
<td>Evacuated tube collector with SS (ETC)</td>
<td>0.65</td>
<td>2</td>
<td>90 – 130 °C</td>
<td>Space heating, Cooling, Process heat</td>
</tr>
<tr>
<td>ETC with compound parabolic concentrator (CPC)</td>
<td>0.60</td>
<td>1</td>
<td>110 – 200 °C</td>
<td>Space heating, Cooling, Process heat</td>
</tr>
</tbody>
</table>
Plastic Absorber

SOLARFLEX

POLYTUB

SOLKAV

AST

GEBAU

EPISOL

SET

ENERFOL
Integrated storage-collector

Cross-section trough a storage-collector
Integrated storage-collector

Source: KIOTO – Clear Energy
Technical concept of an integrated storage-collector

Solcratfé® is available in three different designs that differ by their tank capacity:

Source: KIOTO – Clear Energy
Flat plate collectors
FLAT-PLATE COLLECTOR

Source: IEA SHC Task 33
FLAT-PLATE COLLECTOR

- Absorber
- Transparent cover
- Framework structure
- Connection pipe
- Insulation
- Heat transfer medium pipe
Strip absorber
Large-scale absorber consisting of one big copper sheet
Meander absorber and harp absorber
Aluminium Rollbond absorber with bionic channel structure

Source: Fraunhofer ISE
High Vacuum Flat-plate Collector - SBB

Source: SRB, Valencia, Spain
High Vacuum Flat-plate Collector – TVP (CH)

High vacuum flat-plate collector by TVP SOLAR in Masdar City (Abu-Dhabi, UAE)
TVP High Vacuum Flat-plate Collector with Solar KEYMARK certified up to 200°C
Glass-metal seal

Evacuated at almost 300°C during the manufacturing process
Source: TVP Solar SA
High Vacuum Flat-plate Collector – TVP

Peak efficiency operated at $T_m - T_a = 140^\circ C$ as a function of internal pressure
Vacuum check by a barium mirror spot. It turns from silver to white because of oxidation due to the residual gas inside the panel envelope if the vacuum is lost.

Source: TVP Solar SA
High Vacuum Flat-plate Collector – TVP (CH)
Direct and diffuse solar radiation available at selected locations worldwide

Source: METEONORM data
CPC - COLLECTOR

Source: Solarfocus
Evacuated Tube Collectors
Evacuated Tube Collectors

(d) Bellows
Tube
Absorber
Glass Envelope
Cap

(e) Glass-Metal Seals
Inlet & Outlet
Tube
Glass Envelope
Absorber

(f) Heat Pipe
Glass Envelope
Absorber
Fluid Circulating Tube
Condenser
Heat Exchanger Block
Error–indication

Vacuum present

Vacuum faulty

Evacuated Tube Collectors

Heatpipe, Vitosol 300 (left) / Direct coupled Sydney Collector (right)
Evacuated Tube Collectors – Heat Pipe
Heat Pipe Principle
Heat Pipe Principle – Wet Connection
Thermosyphon system with evacuated tube collectors

Source: http://greenterrafirma.com/evacuated_tube_collector.html
Evacuated Tube Collectors
Concentrating Collectors
Parabolic Trough Collector

- Glass encased absorbent-coated receiver tube
- Parabolic shape with reflective coating
- Flex-hose to carry transfer fluid to/from receiver tube
Working Principle - PTC

Parallel sun rays being concentrated onto the focal line of the collector

Small parabolic trough collector on the test rig of AEE INTEC
Tracking of the sun

Collector axis oriented north-south
Linear concentrating fresnel collector

Source: W. Weiss and M. Rommel: Process heat collectors, IEA SHC Task 33
Solar cooling system with Fresnel concentrator collectors for a show-case football stadium in Doha, Qatar

Source: Industrial Solar
WORKING PRINCIPLE

Raytracing with vertical irradiation.
Left: cross section of the whole collector
Right: cross section of the receiver with secondary concentrator
Physical Processes inside a Flat-Plate Collector

- Occurrence of solar radiation
- Reflection on the pane of glass
- Heat loss through the pane of glass
- Reflection on absorber
- Heat loss through the rear and side walls
Losses of a basic Flat-plate Collector

COLLECTOR MATERIALS
## ABSORBER MATERIALS

### THERMAL CONDUCTIVITY

<table>
<thead>
<tr>
<th>absorber material</th>
<th>thermal conductivity [W/mK]</th>
</tr>
</thead>
<tbody>
<tr>
<td>steel</td>
<td>50</td>
</tr>
<tr>
<td>aluminium</td>
<td>210</td>
</tr>
<tr>
<td>copper</td>
<td>380</td>
</tr>
</tbody>
</table>
**ABSORBER COATING**

Selective coating: \(0 \leq \varepsilon < 0.2, \ \alpha > 0.9\)

Partially selective coating: \(0.2 \leq \varepsilon < 0.5, \ \alpha > 0.9\)

Non selective coating: \(0.5 \leq \varepsilon < 1.0, \ \alpha > 0.9\)

PLAIN COPPER
black paint
galvanic coating
physical vapour deposition or sputtering
ABSORBER COATING

Source: Alanod-Sunselect / ESTIF
Video: TiNOX High Selective Coating.flv
<table>
<thead>
<tr>
<th>Cover</th>
<th>Thickness [mm]</th>
<th>Weight [kg/m²]</th>
<th>Solar transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard glass *)</td>
<td>4</td>
<td>10</td>
<td>0.84</td>
</tr>
<tr>
<td>Standard glass, tempered</td>
<td>4</td>
<td>10</td>
<td>0.84</td>
</tr>
<tr>
<td>Iron free glass, tempered</td>
<td>3.2</td>
<td>8</td>
<td>0.91</td>
</tr>
<tr>
<td>Antireflective coated glass</td>
<td>3.2</td>
<td>8</td>
<td>0.95**</td>
</tr>
<tr>
<td>PMMA, ducted plate</td>
<td>16</td>
<td>5.0</td>
<td>0.77</td>
</tr>
<tr>
<td>PMMA, double ducted plate</td>
<td>16</td>
<td>5.6</td>
<td>0.72</td>
</tr>
</tbody>
</table>

*) Danger of breaking determined by high collector temperatures
**additional costs low and worthwhile
# Insulating Materials

<table>
<thead>
<tr>
<th>Insulating Material</th>
<th>Max. Allowable Temperature [°C]</th>
<th>Density [kg/m³]</th>
<th>Conductivity [W/mK] at 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral wool</td>
<td>&gt; 200</td>
<td>60 - 200</td>
<td>0.040</td>
</tr>
<tr>
<td>Glass wool</td>
<td>&gt; 200</td>
<td>30 - 100</td>
<td>0.040</td>
</tr>
<tr>
<td>Glass wool</td>
<td>&gt; 200</td>
<td>130 - 150</td>
<td>0.048</td>
</tr>
<tr>
<td>Polyurethane foam</td>
<td>&lt; 130</td>
<td>30 - 80</td>
<td>0.030</td>
</tr>
<tr>
<td>Polystyrol foam</td>
<td>&lt; 80</td>
<td>30 - 50</td>
<td>0.034</td>
</tr>
</tbody>
</table>
Characteristic Values of Flat-plate and Evacuated Tube Collectors

\[ \dot{Q}_{\text{coll}} = F_R (\tau \alpha) G - F_R U_L \Delta T \]

\( Q_{\text{coll}} \) is the energy collected per unit collector area per unit time

\( FR \) is the collector’s heat removal factor

\( T \) is the transmittance of the cover

\( \alpha \) is the shortwave absorptivity of the absorber

\( G \) is the global incident solar radiation on the collector

\( UL \) is the overall heat loss coefficient of the collector

\( T \) is the temperature differential between the heat transfer fluid entering the collector and the ambient temperature outside the collector.
Collector Efficiency Curve

\[ \frac{(t_m - t_a)}{G} [\text{Km}^2/\text{W}] \]
Collector Efficiency

\[ \eta = \frac{\text{useful energy}}{\text{solar energy}} \]

\[ \eta = \eta_0 - a_1 \cdot \frac{(t_m - t_a)}{G} - a_2 \cdot \frac{(t_m - t_a)^2}{G} \]
**Collector Efficiency**

\[ \eta_0 \text{ maximum efficiency } (= \text{efficiency at } t_m = t_a) \]

- \( \mathbf{a_1} \) linear heat loss coefficient \( \frac{W}{m^2 \cdot K} \)

- \( \mathbf{a_2} \) quadratic heat loss coefficient \( \frac{W}{m^2 \cdot K^2} \)

\( t_m \) average temperature of the heat transfer fluid °C

\( t_a \) ambient temperature °C

\( G \) incident radiant energy (global radiation) \( \frac{W}{m^2} \)

s. T-Sol Collector data

[www.aee-intec.at] AEE - Institute for Sustainable Technologies
Efficiency curves for different flat-plate and evacuated tube collectors

![Graph showing efficiency curves for different solar collectors. The x-axis represents (t_m - t_a)/G [Km^2/W], and the y-axis represents eta. Graph contains lines for Evacuated Tube Collector, Selective Flat-plate Collector, Uncovered Absorber, and Simple Flat-plate Collector.]
Efficiency of different collector types (calc)

This range has been calculated assuming 400 and 500 kWh/(m²*a) as minimum and maximum average solar energy yield. The equation for the efficiency is given as \( \eta = \frac{(t_m - t_a)}{G} \) [Km²/W].

- Evacuated Tube Collector
- Simple Flat-plate Collector
- Uncovered Absorber
- Selective Flat-plate Collector
Area Definitions

Aperture area

Absorber area

Gross area
Area Definitions

- A: Absorber area
- B: Aperture area
- C: Gross area
Thank you for your attention