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Solar thermal systems

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Instructions and general information

- Please mute your microphones
- Meeting will be recorded
- Slides will be shared after call
- Questions should be posted to:

Learning objectives

1. Fundamentals of solar thermal energy
2. Types of solar thermal DHW systems
3. Solar thermal DHW systems design principles
4. Thermprotect overheating protection

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Harvest free energy from sun

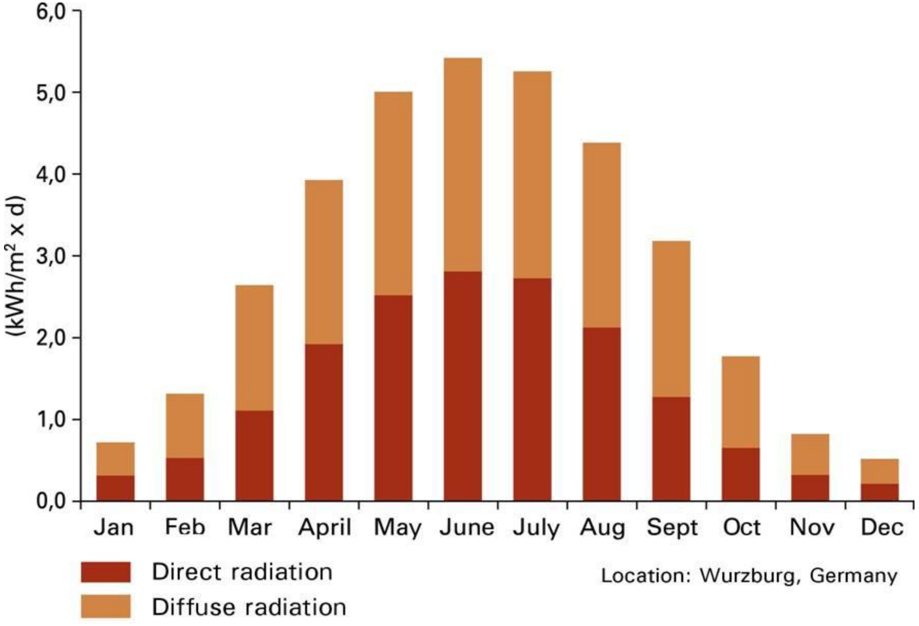
CO_2 Emission reduction

Offset fossil fuel cost

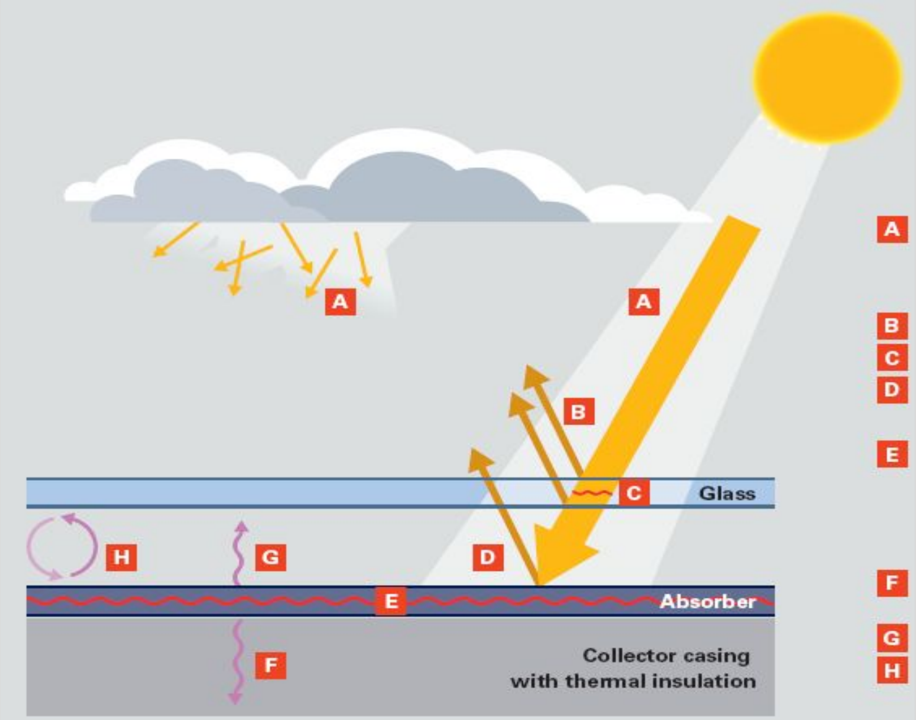
Solar principle and collector performance

Solar principle and collector performances

Every location on earth has different radiation levels



Collector performance



A - Insolation to collector

OPTICAL LOSSES

B - Reflection off the glass pane
C - Absorption in the glass pane
D - Reflection of the absorber

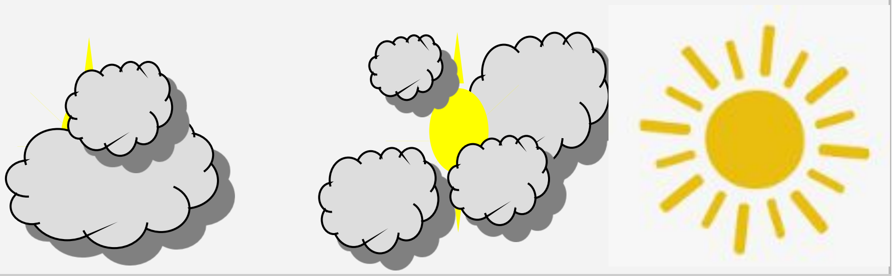
E - Absorber sheet heated by solar radiation

THERMAL LOSSES

F- Thermal conduction of collector material
G - Absorber heat radiation
H - Convention

Collector performance

1x Vitosol 200-FM Flat Plate



Mostly Cloudy	Mixed Sun & Cloud	Full Sun
200 W/m²	600 W/m²	1000 W/m²
Peak Output Per Collector:		
382 Watts	1146 Watts	1909 Watts

*Table is intended for reference purposes only!

Collector performance

How do you predict how much energy a collector will produce?

3 x Vitosol 200FM Collectors
3 x 2.33 ft^2 = 6.99 m^2 (aperture)

Estimated Maximum Peak Hourly Output:

6.99 m^2 x 700 W = **4.9 kW**

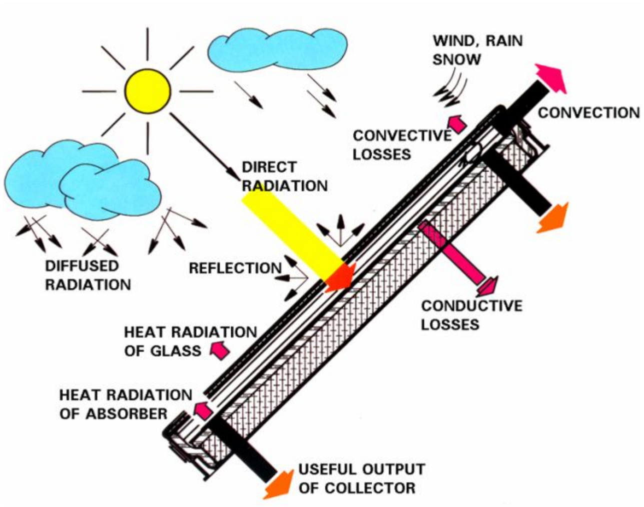
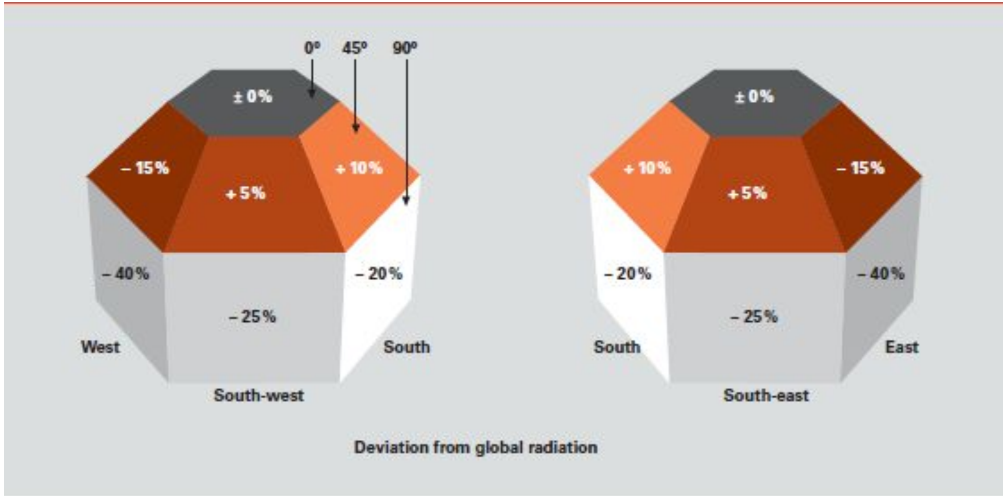


*Table is intended for reference purposes only!

Collector Orientation
Inclination

Subject to the angle and orientation of a surface, the level of insolation relative to a horizontal area reduces or increases.



The amount of energy is greatest when the radiation hits the receiver surface at right angles. This case never arises as one moves away from the equator.

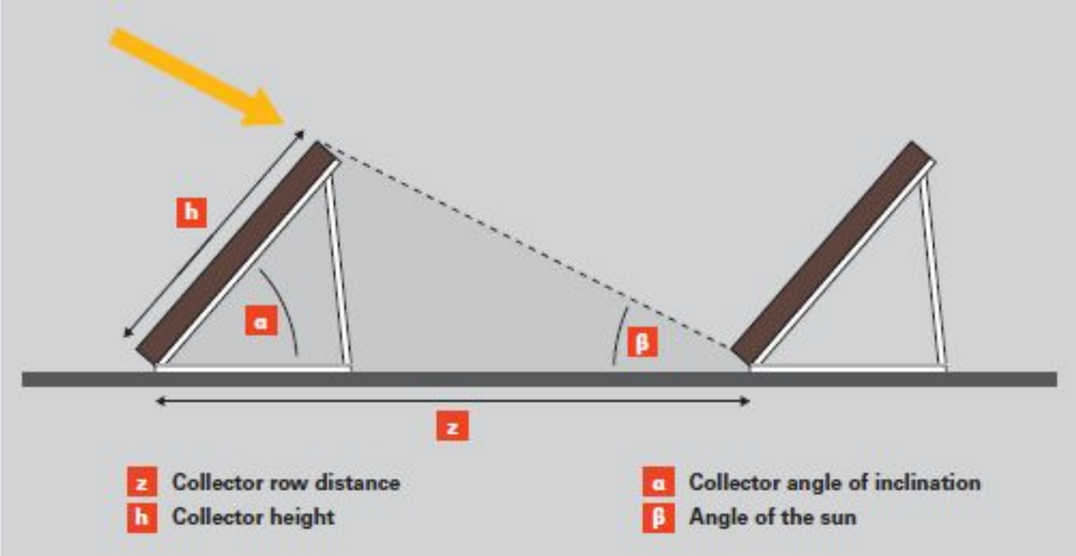
The optimum tilt angle:
Latitude + 15 deg. in winter, and Latitude - 15 deg. in summer.
In most cases solar thermal systems are optimized for winter, the angle of inclination is **fixed at Latitude + 15 deg.**

In the northern hemisphere, the solar collectors should face **true south**, since the sun is always in the southern part of the sky.

Collector Orientation

Spacing

When installing several rows of collectors in series behind each other, suitable clearance to prevent shading must be maintained.



$$\frac{z}{h} = \frac{\sin(180° - (\alpha + \beta))}{\sin\beta}$$

z = Collector row clearance
h = Collector height
α = Collector angle of inclination
β = Angle of the sun

ß = Angle of Sun on mid day on the shortest day of the year (21.12) = ((90 - 23.5) - latitude)

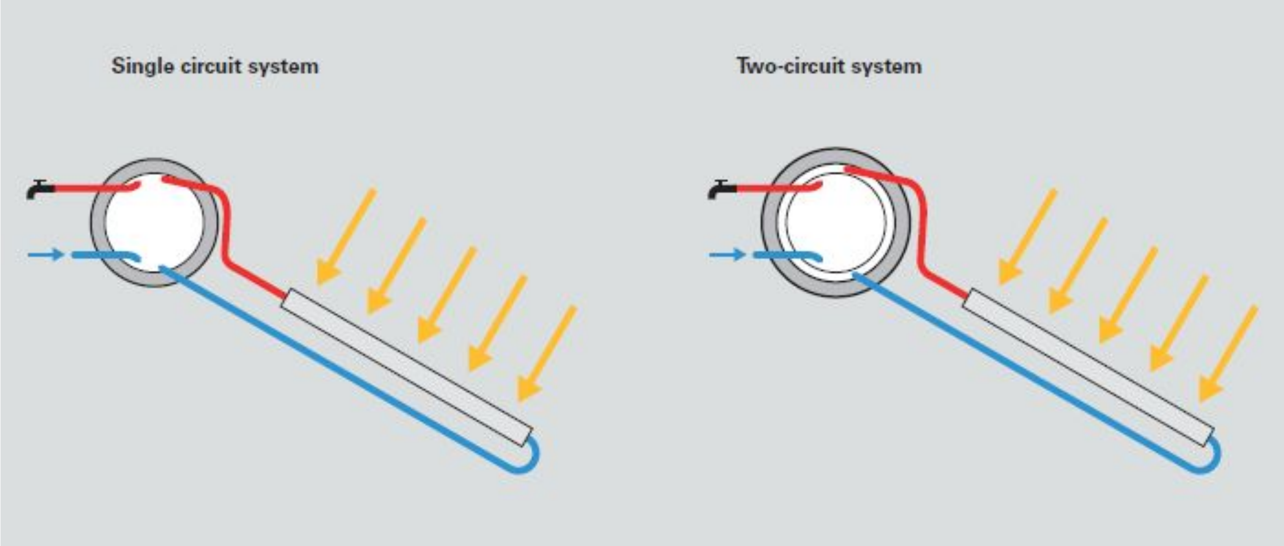
Solar DHW System types

Thermosiphon - Gravity fed

Forced circulation - Pumped

Solar DHW System types

Thermosiphon



Transfer between cylinder and collector is governed by gravity.

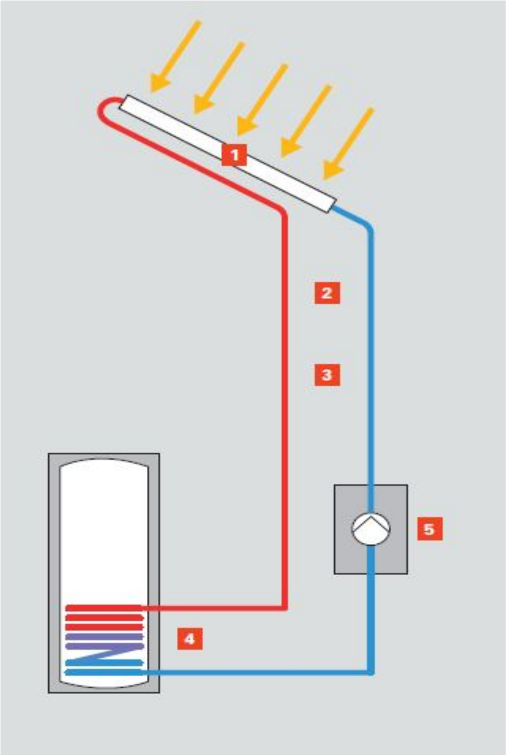
The pressure differential between the hot and cold heat transfer medium is utilised as propulsion energy.

Single circuit: DHW flows directly through the collector, no separate heating medium. Risk of damage by frost and/or poor water quality.

Two circuit: Heat exchanger separates the heated and heating fluids.

Solar DHW System types

Forced circulation



At a minimum a forced circulation solar thermal system comprises collectors, a control unit with pump and a well insulated DHW cylinder.

A pump circulates the heating medium between the collector and the DHW tank following the differential temperature principle. The DHW is indirectly heated via an internal or external heat exchanger. The pump stops when the set DHW temperature is reached.

Solar DHW System types

Quick comparison

		Forced Circulation (FC)		Thermosiphon (TS)
Warm water comfort		High - pump and controller ensures effective transfer of collector energy to DHW		Medium as the circulation is gravity based
System control		Precise through the Vitosolic electronic controller		No control
Over heating protection		Pump cuts off when DHW temperature is reached. Thermprotect absorber coating ensures lower stagnation therefore lower primary circuit temperature		P/T valve in the DHW and PRV+Air vent in the primary circuit. When DHW temp. exceeds set value. DHW is vented in a controlled manner and cold water entering the tank automatically lowers tank temp. The solar circuit can be pressurized to withstand high temperatures
Installation complexity		Medium		Easy
Maintenance		Medium		Low
Lifetime		Hight. All components bar the collectors are / can be installed indoors. Lifetime exceeding 20 years not exceptional		Medium as compared to FC systems

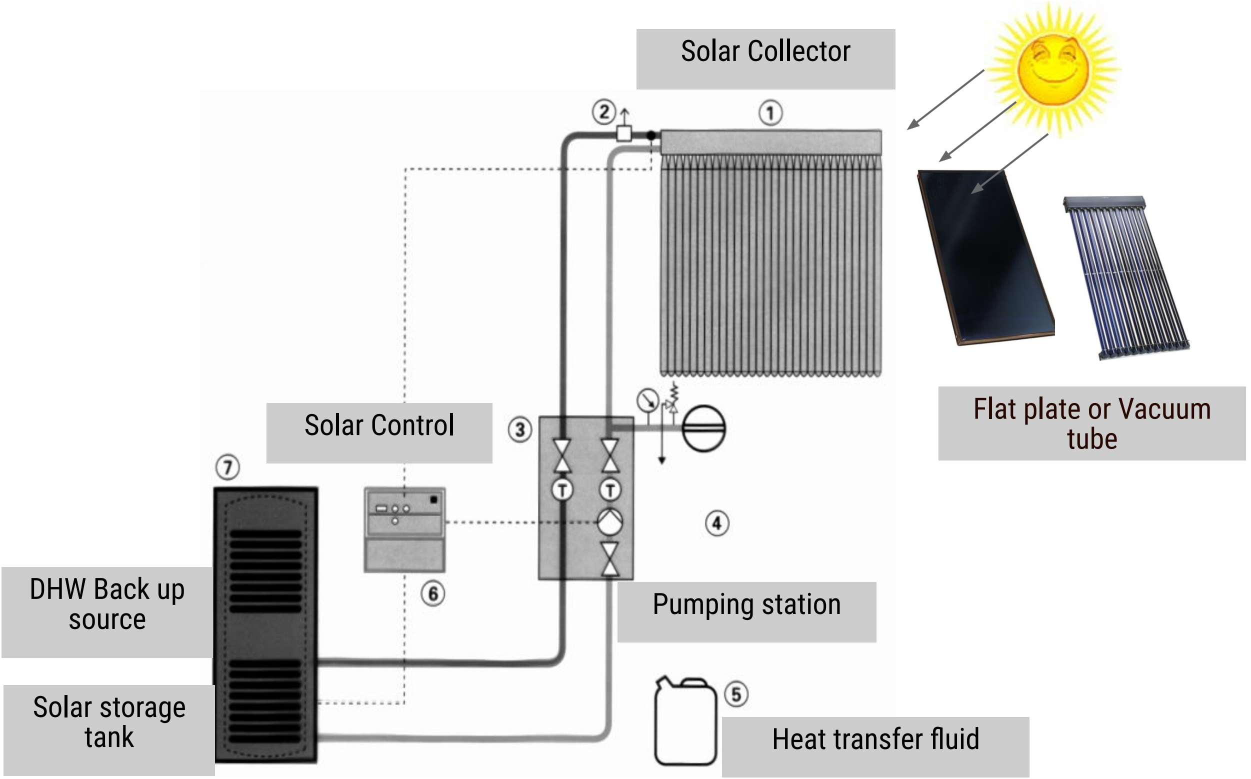
For *Neutral* *Against*

Sizing and design criteria

Pre-design steps for Solar Thermal projects

1. What are the customers expectations?
2. What is the budget for the project?
3. What is the physical size available?
   - Roof space available
   - Building orientation / shading
   - Mechanical room space available
4. What is the DHW load?
   - Lit/day (true consumption)
   - Water delivery temperature
   - Usage profile - Daily, weekly, monthly
5. What is the back up required?
6. What is the target energy offset or carbon emissions reduction?

Solar thermal systems - main components



Collector selection

How to decide which one is the best for the project

LOW Temperature

Seasonal pool heating

MEDIUM Temperature

Year Round Pool Heating

Domestic Hot Water

Supplemental Space Heating

HIGH Temperature

Process heating

Sizing and design criteria

How many collectors? How much storage?

Sizing and design criteria
Estimating DHW demand

How big is DHW load?

- Estimate the ***average daily*** DHW load

Residential homes:
60 – 75 L
DHW / Person / Day

Multi-family apartments:
38 - 45 L
DHW / Person / Day

Sizing and design criteria
Collector selection

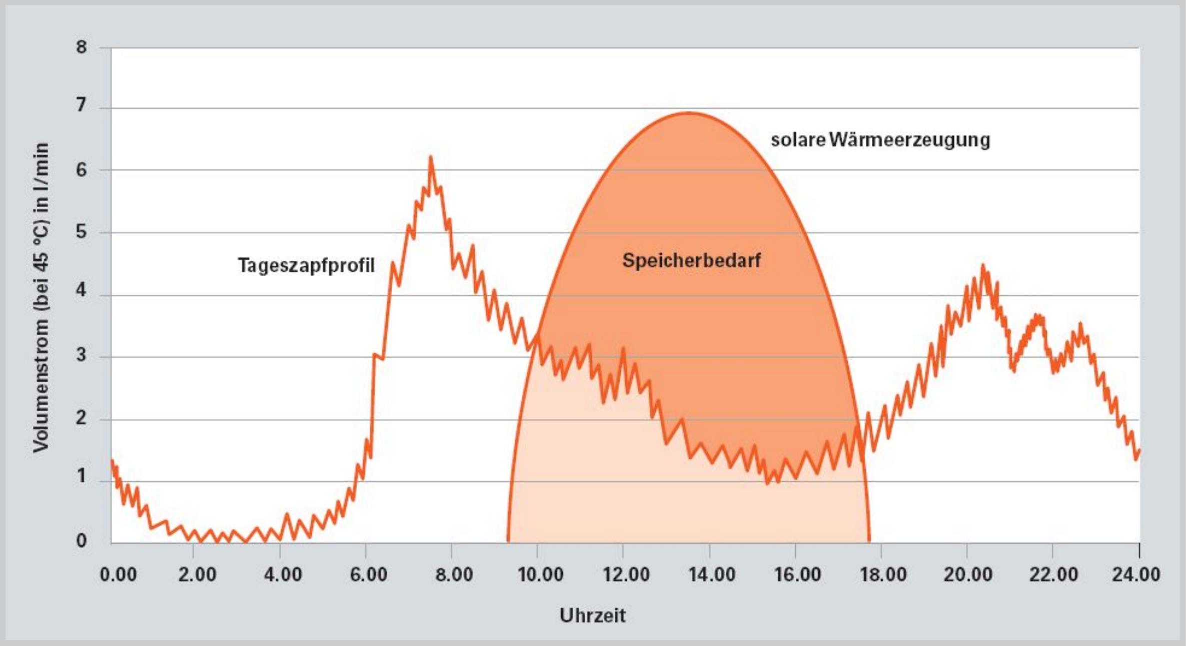
Recommended ratio:
+/- 2 sqm of collector area per person for first two occupants

+/- 1.5 sqm for each additional occupant
* Viessmann Solar Collector area is 2.51 sqm

Example:
2 occupants = 4 sqm
3 occupants = 4.5 sqm
4 occupants = 6 sqm

Sizing and design criteria

Storage sizing



The daily water use profile of the occupants, does not match when the solar radiation is delivered

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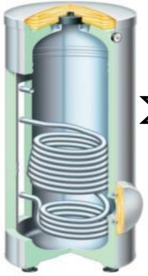
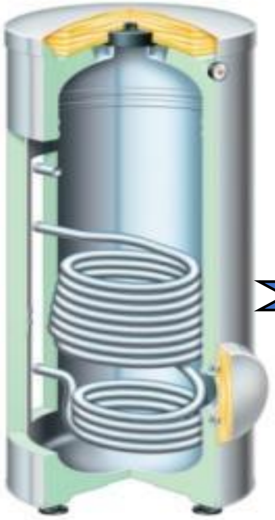
Sizing and design criteria
Storage sizing

Rule of 

50 - 80 l / m2 collector aperture area





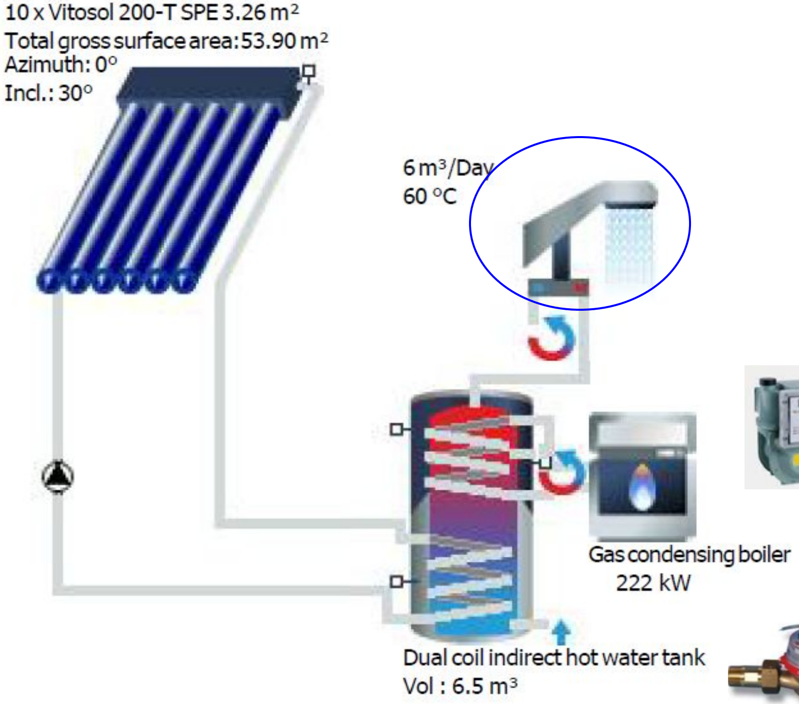
Sizing and design criteria

Design software - how does it work?

T*SOL®

- *Data:* Historical weather data (radiation and air temps)
- *Inputs:* DHW usage load, quantity and type of collectors, storage volume, piping, etc
- *Calculates:* All energy flow in solar system including:
    - Solar radiation on collectors
    - Collector efficiency
    - Pipe and tank losses
- *Predicts:* Energy output of solar system, solar fraction, system efficiency, fuel savings, GHG emissions, etc

Sizing and design criteria
DHW Demand

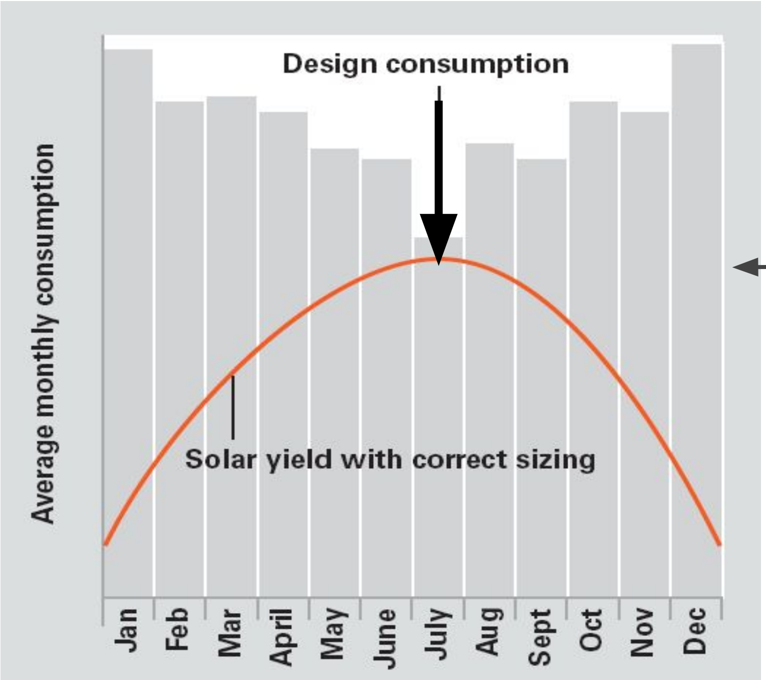


How to estimate DHW demand?

- Use ASHRAE or VDI methods for greenfield projects.
- For retrofit projects, monitor gas / electricity consumption, and
- Cold water supply to DHW tanks (if applicable)

Sizing and design criteria

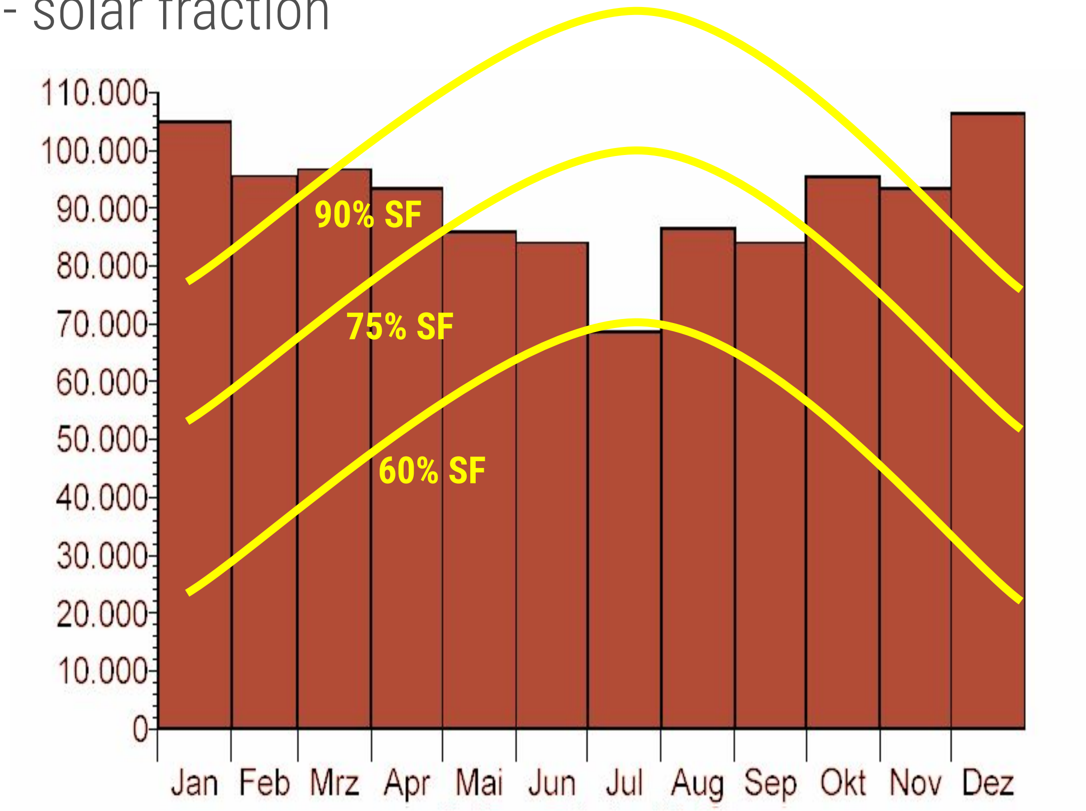
Sizing parameters



Size for the lowest expected load during the best conditions of the Summer

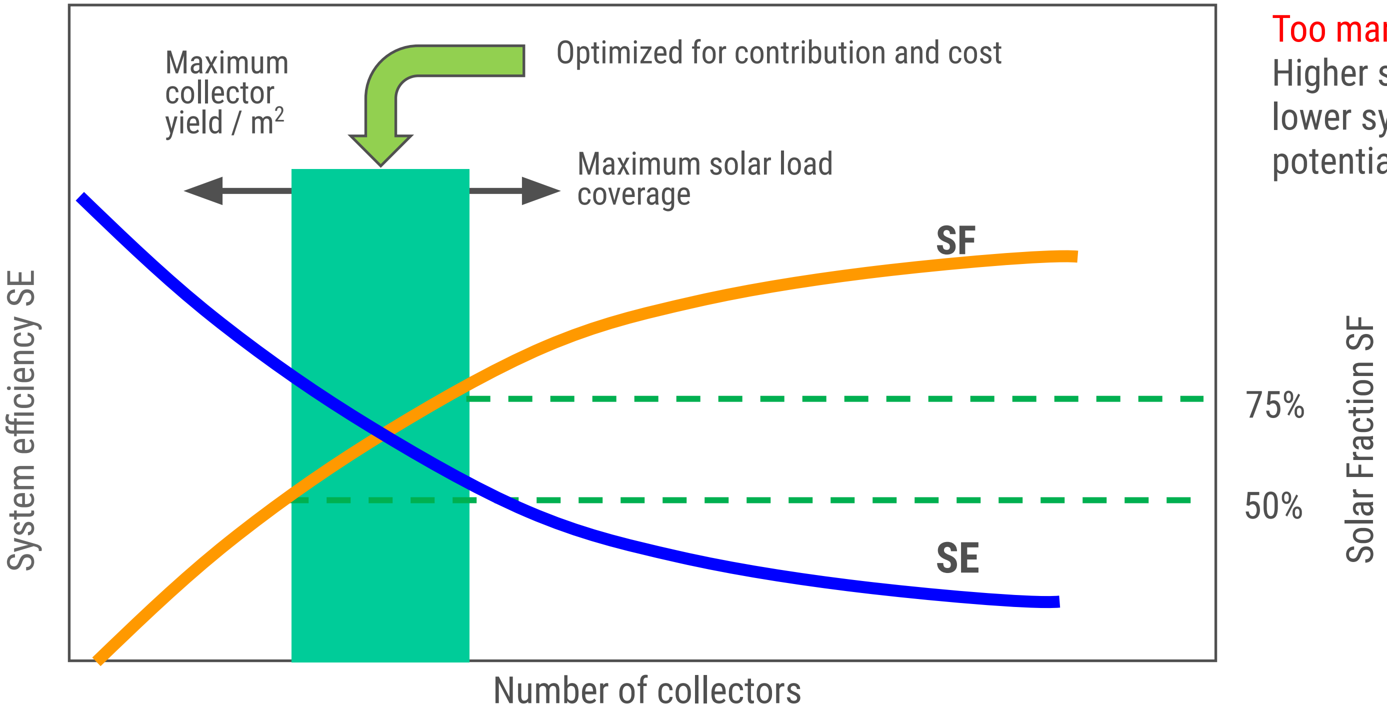
Sizing and design criteria

Sizing parameters - solar fraction



Sizing and design criteria

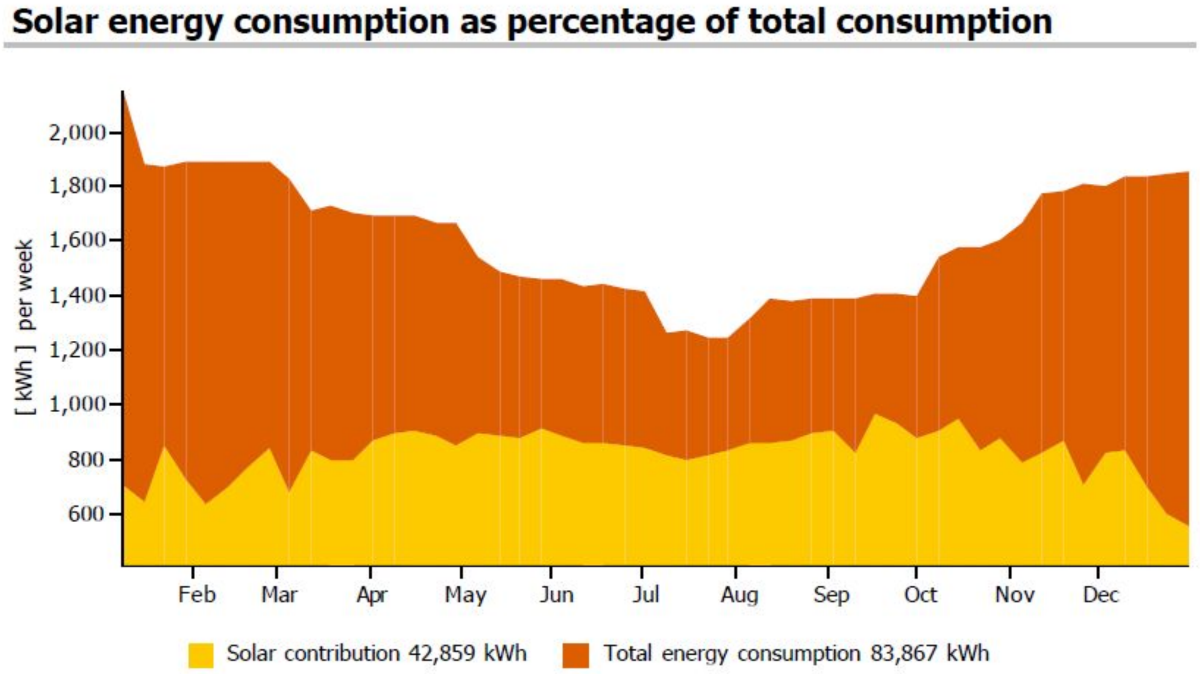
Solar fraction v. Efficiency



Too many collectors = Higher solar fraction, lower system efficiency, potential to overheat

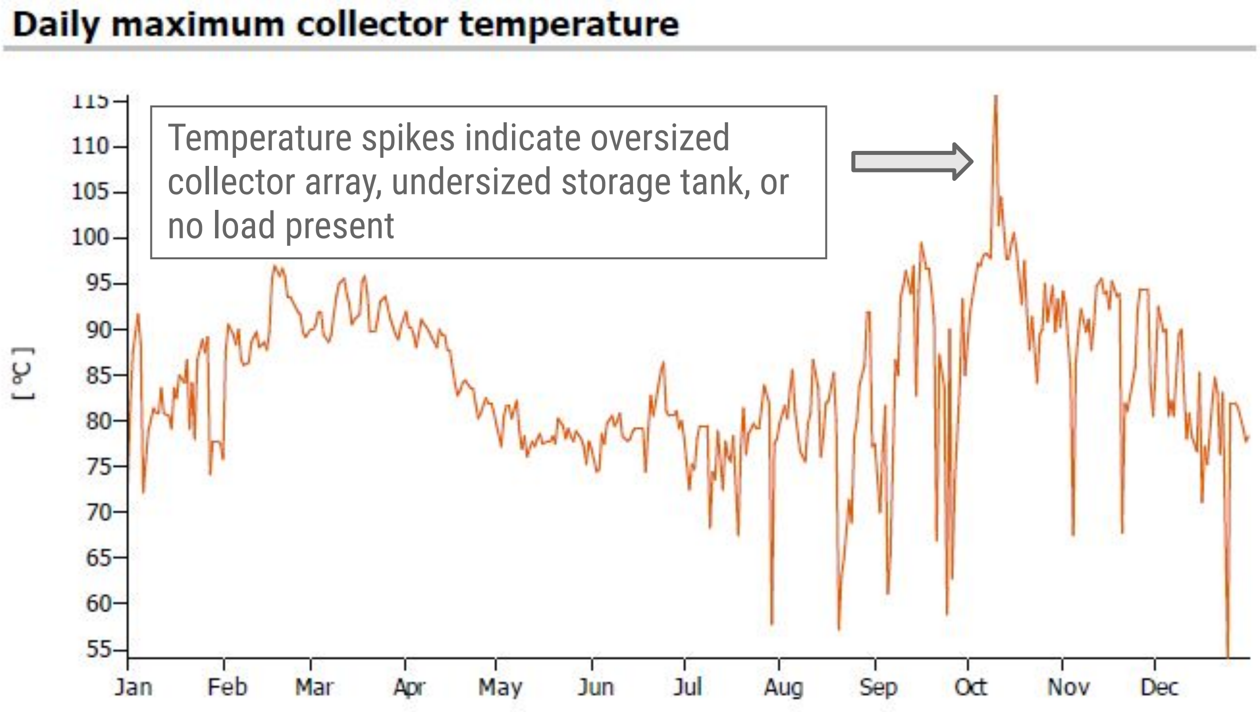
Sizing and design criteria

Graphical display of system performance



Sizing and design criteria

Graphical display of of over heating



Overheating protection

Over heating protection - why?

The best solar water heating applications:

- High volume, constant DHW consumption, Recirc. loops
- High usage during day
- 7 days per week usage
- 12 months per year usage

Below is a list of ideal applications for solar thermal systems:

- Domestic Hot Water
- Pool Heating
- Multi-family homes
- Hotels
- Nursing homes
- Community centers
- Car wash
- Laundromats
- Firehalls
- Restaurants, etc.

Poor applications for solar thermal:

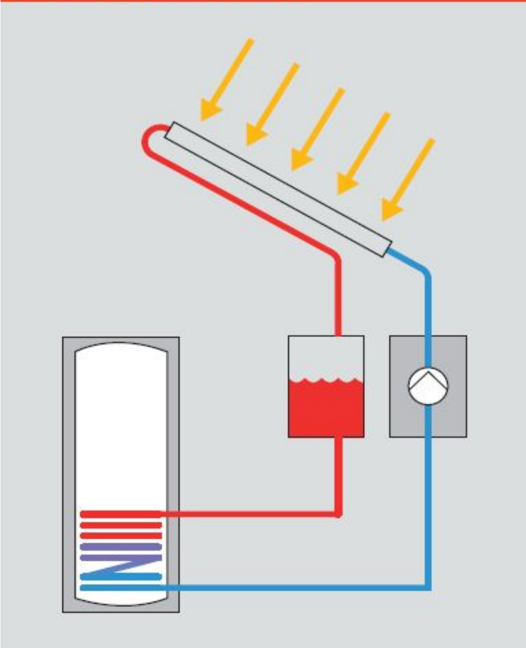
- Intermittent or erratic loads
- Low usage in summer
- No usage on weekends

Most susceptible to issues with overheating - require protection

Over heating protection

The story so far.. Drainback systems

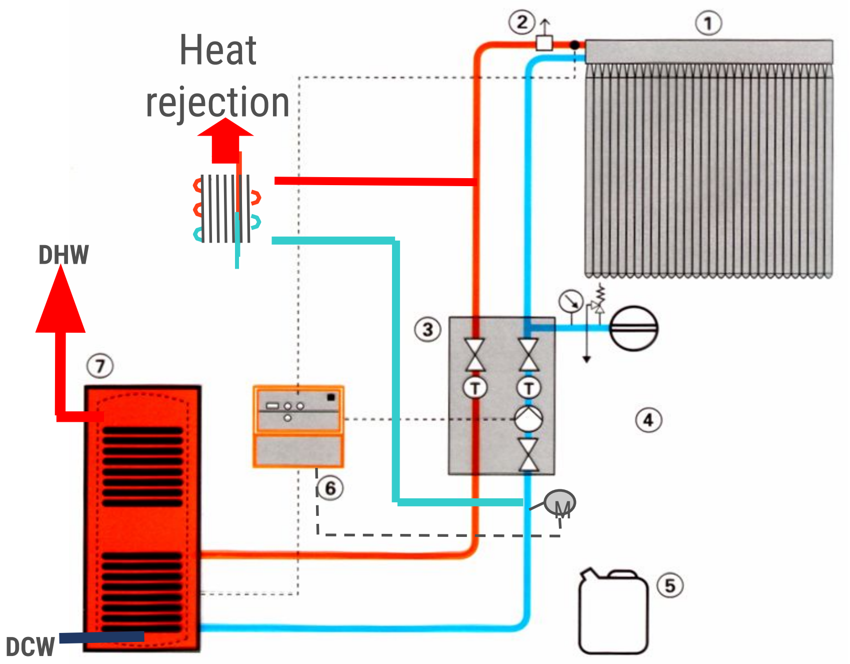
Fig. A.3.3 Drainback system



- Heat transfer fluid
- Overheat protection – gravity
- Typical systems are open to atmosphere – no expansion tanks or relief valves required
- All piping must be carefully planned to ensure proper drainage of system. Large pumps required to fill piping for proper operation
- Once collector temperature exceeds 100°C, (212°F), solar pump must stay off or fluid flashes to steam upon entering hot collectors

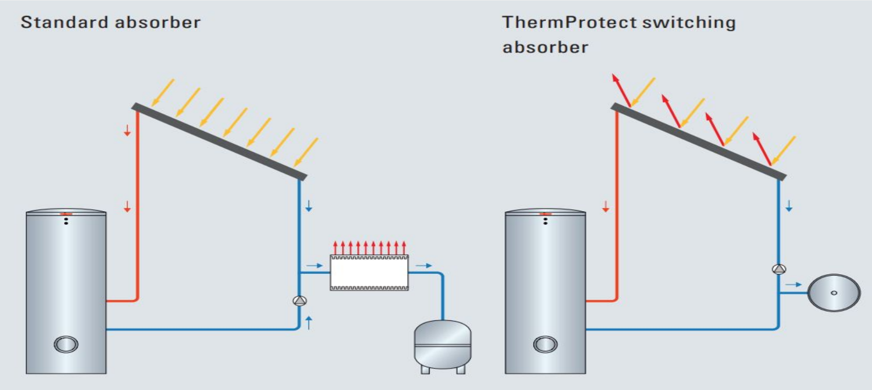
Over heating protection

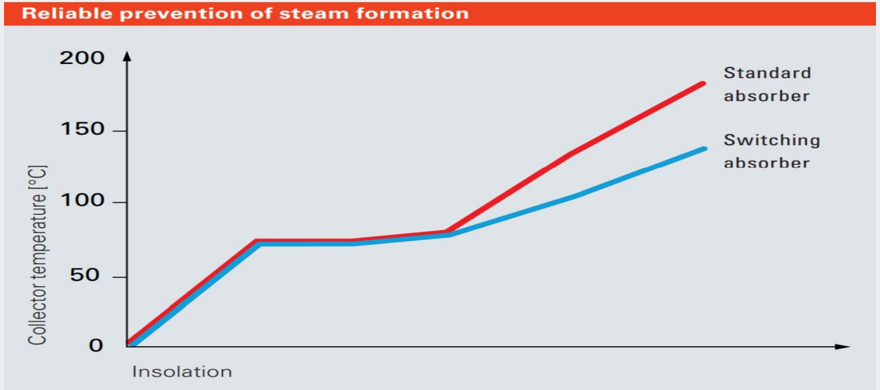
The story so far.. Closed loop System

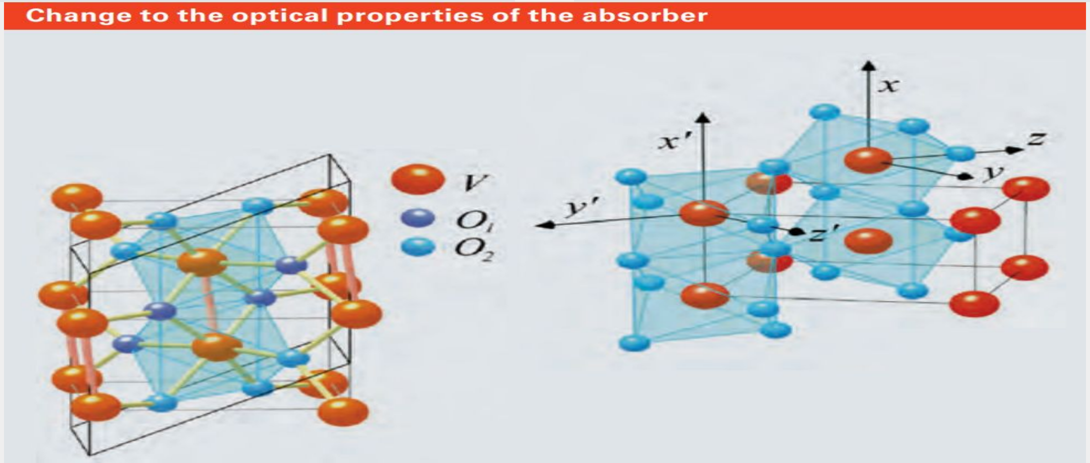


- Direct heat rejection using a dry cooler / fan coil unit
- Added system complexity, more moving parts, fan coil unit requires controller.

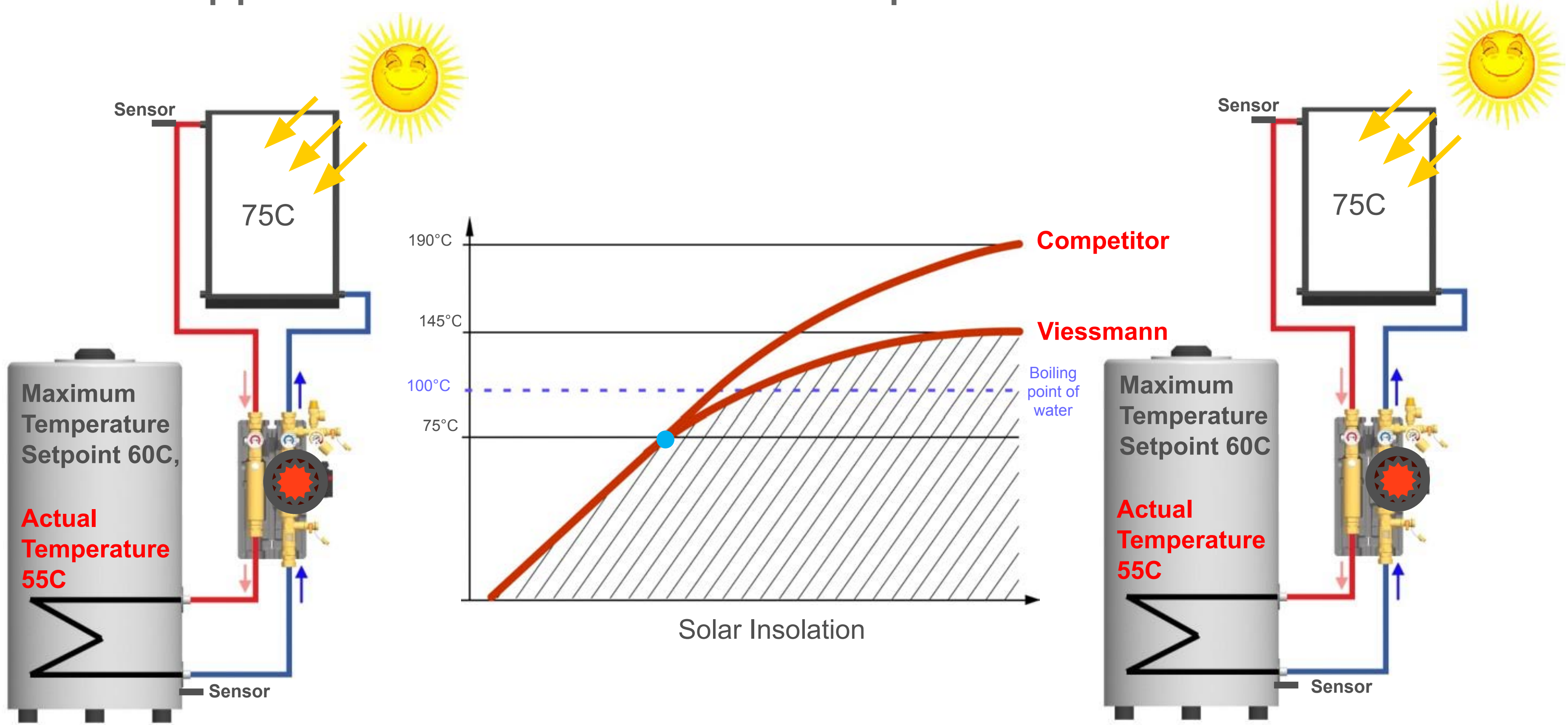
Viessmann Solar collector with thermoprotect absorber







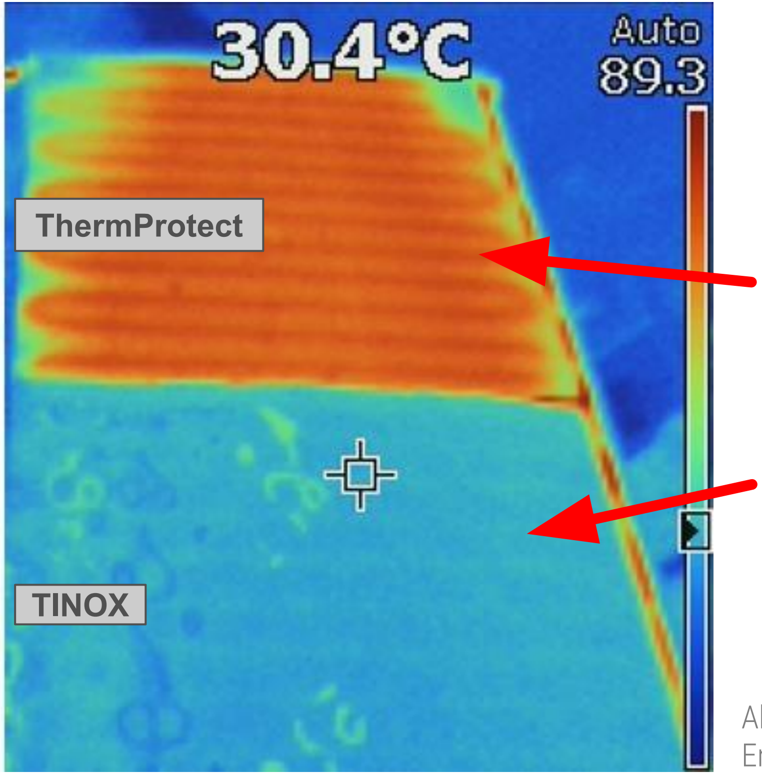
ThermProtect
What happens when the circulation stops



ThermProtect

Viessmann Collector With Multiple Selective Surface Coatings

ThermProtect vs. TINOX



- Hot water injected into the collector to trigger the ThermProtect coating (> 75°C). The absorber emissivity will increase from ~7% up to 40%.
- Absorptivity (~95%) High emissivity (~40%)
  *Excess heat is being rejected from the absorber.
- Absorptivity (~95%) Low emissivity (~7%)
  *Excess heat is <u>not</u> being rejected from the absorber.

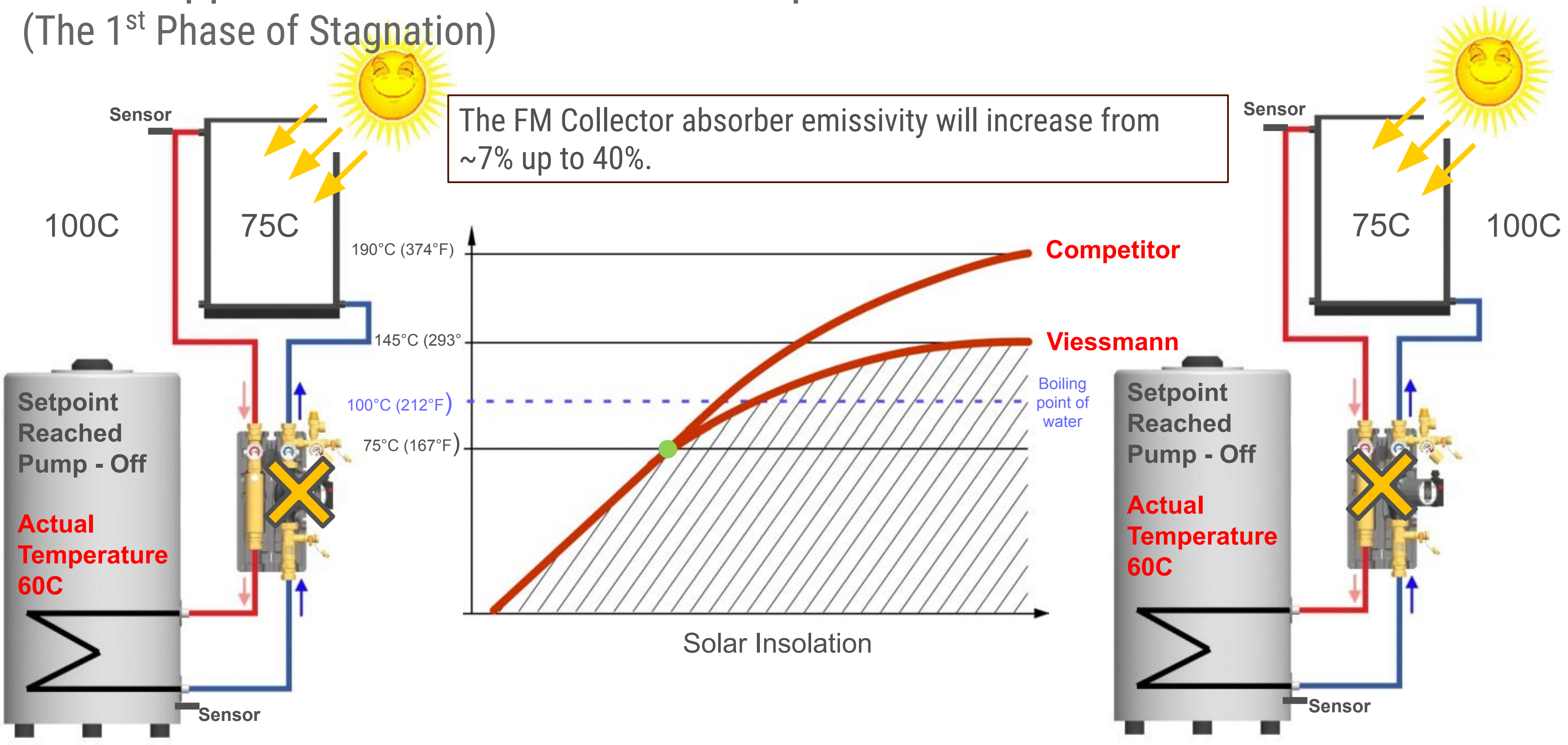
Absorptivity: is the ability to capture short wave radiation from the sun.
Emissivity: is the ability to reject long wave radiation from the surface.

ThermProtect

What happens when the circulation stops

(The 1st Phase of Stagnation)

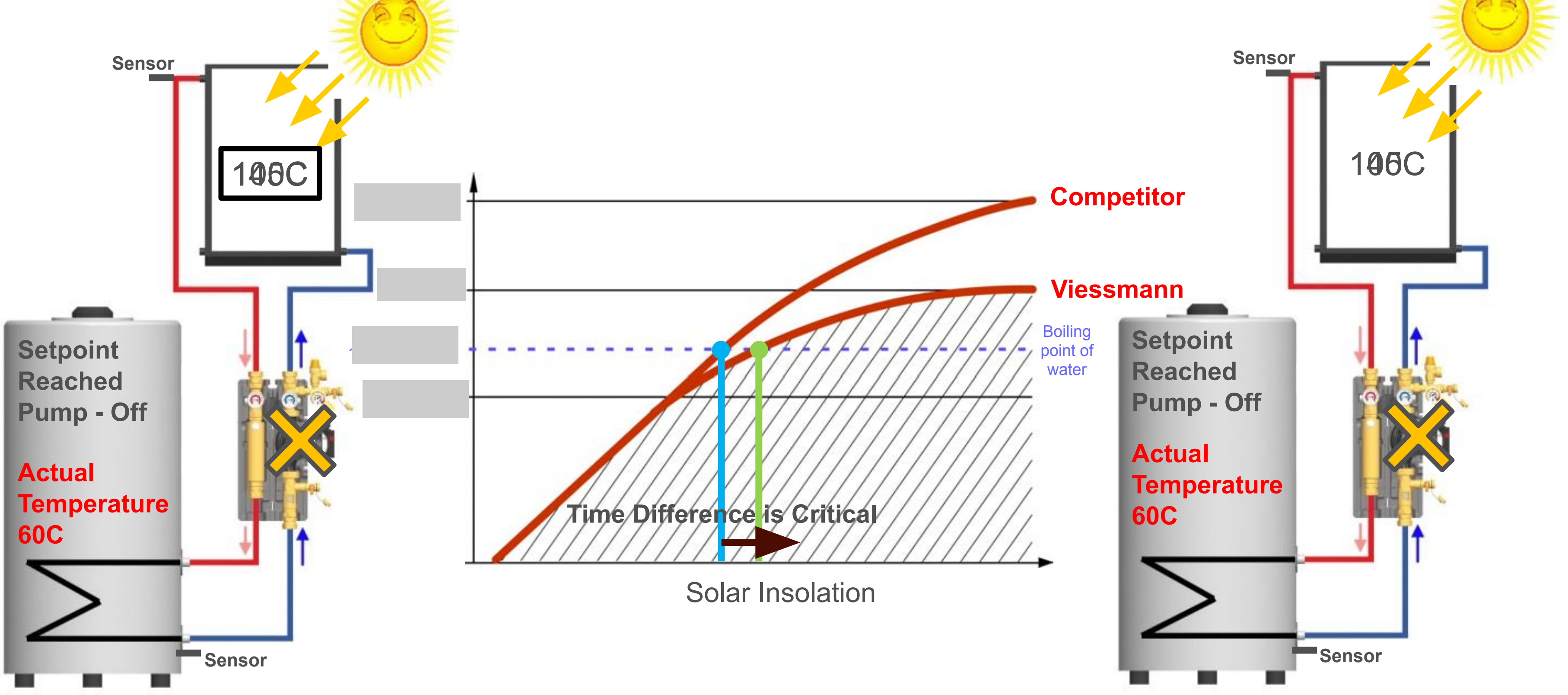
The FM Collector absorber emissivity will increase from ~7% up to 40%.



ThermProtect

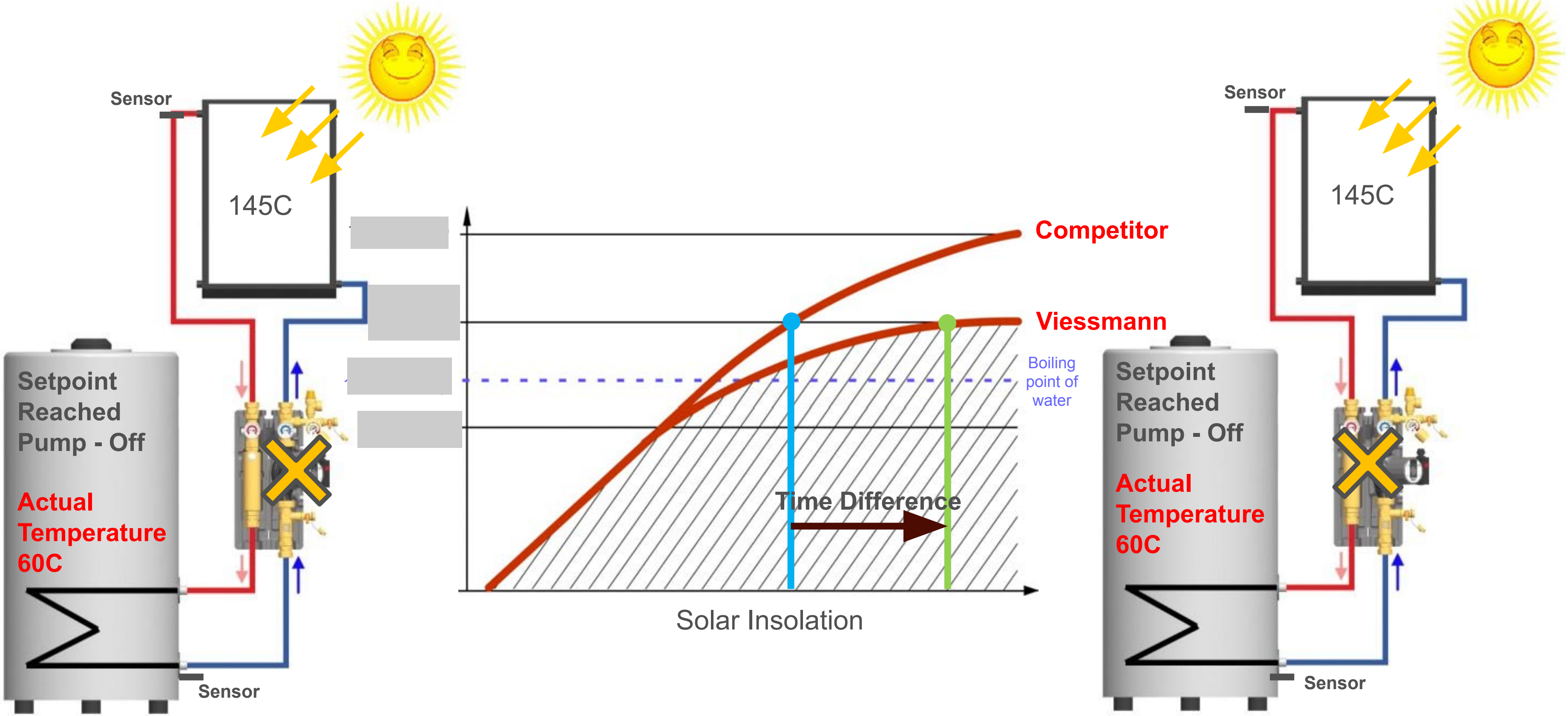
What happens when the circulation stops

(Temperature rise, Fluid Volume Expands Pressure increases in the System)



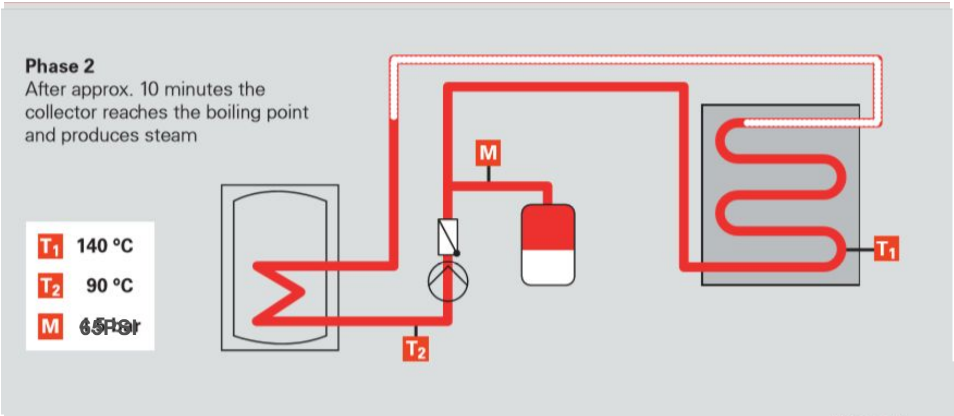
ThermProtect

What happens when the circulation stops (Phase 2 of Stagnation)



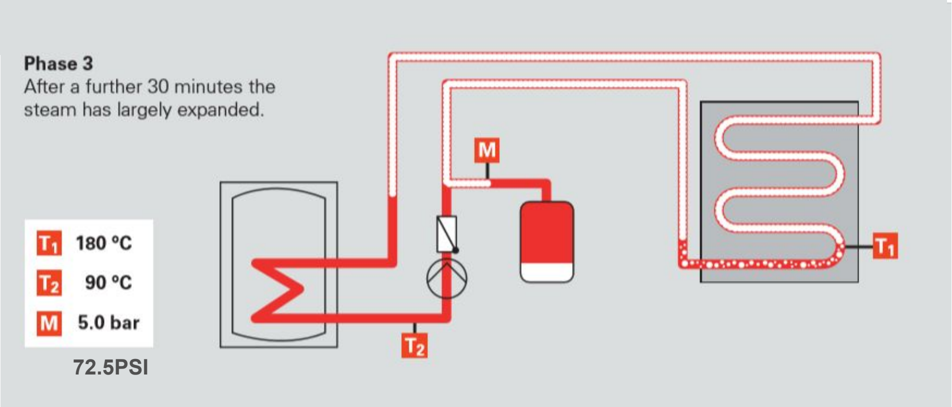
ThermProtect

Stagnation : 5 Phases



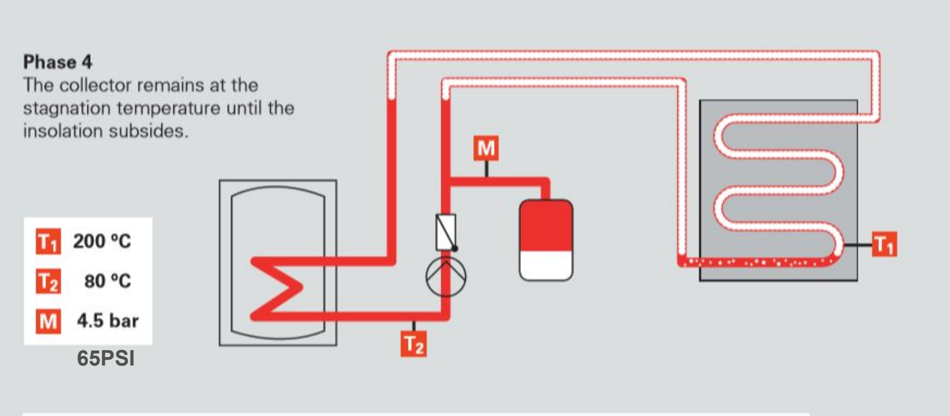
Phase 1: Liquid expansion
During insolation, the medium no longer circulates because the solar circuit pump has been switched off. The heat transfer medium volume expands and the system pressure increases by approx. 1 bar, until the boiling temperature has been reached.

Phase 2: Evaporation of the heat transfer medium
At the boiling point, steam forms inside the collector; the system pressure rises further by approx. 1 bar. The medium temperature will be approx. 140 °C.



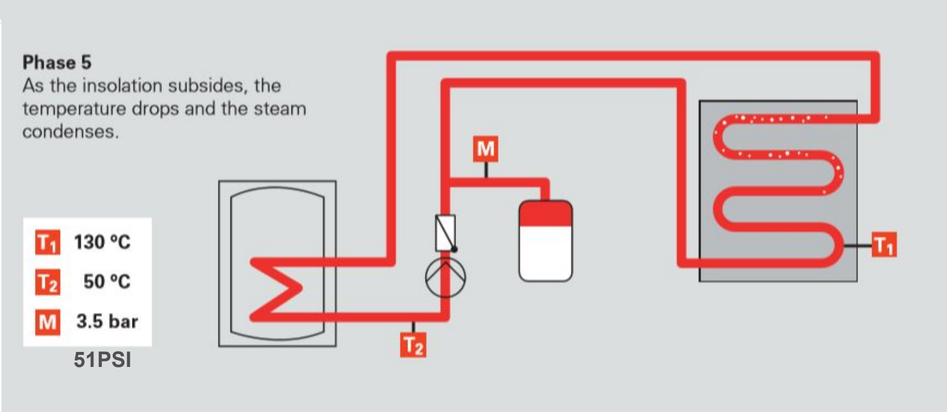
ThermProtect

Stagnation : 5 Phases (cont.)



Phase 4: Superheating
The medium concentration results in progressively less water being able to be evaporated. Consequently, the boiling point rises and consequently the temperature inside the collector. As a result, the collector output falls and the amount of steam in the system drops off. The pressure drops and the temperature in the collector reaches the stagnation temperature. This condition continues until the insolation is inadequate for holding the collector at stagnation temperature.

Phase 5: Refilling the collector
When insolation reduces, the collector temperature and system pressure fall. The steam condenses and the heat transfer medium is pushed into the collector. If liquid meets overheated collector parts, minor steam hammer can still occur.



Solar Heat Transfer Fluids

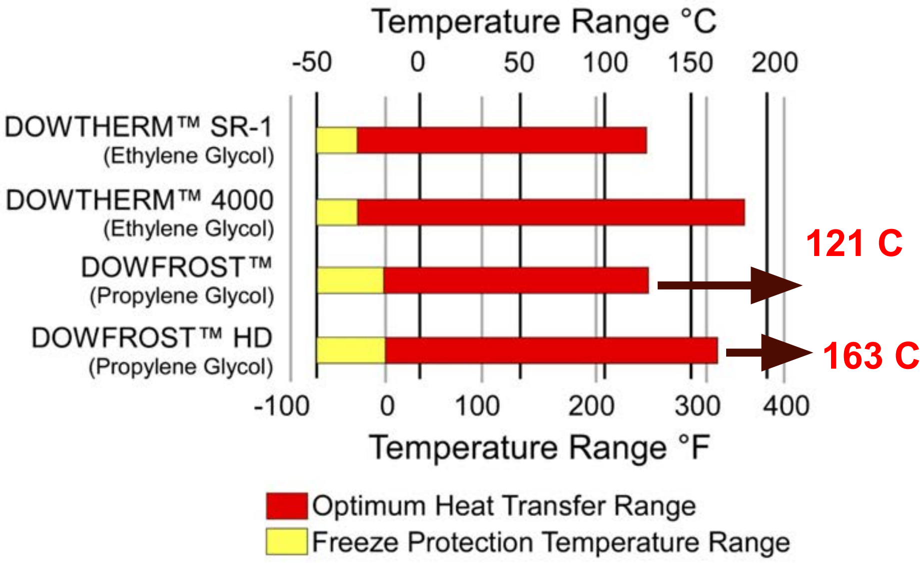
At temperatures higher than 121C, (250°F), glycols degrade severely forming acid molecules, properly inhibited glycols at high temperatures up to 176C, (350°F), typically for only short periods, or causes chemical change, (darkening of fluid, decomposition, pH drop)

Tyfocor HTL Solar fill:

- Designed for solar heating systems with high stagnation temperatures
- Temperature stable up to 170°C

Fig. B.3.4–1 Severely degraded heat transfer medium

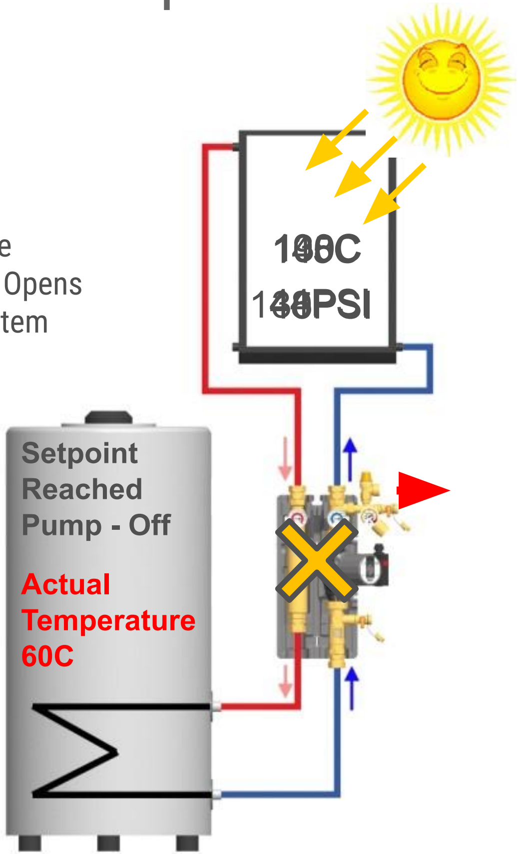
Dowfrost Propylene Glycols:



ThermProtect

Vapour Pressure Adjustment – boiling point of fluid depends on pressure of fluid in collectors

Above Orange Line
Solar Relief Valve Opens
Recharging of system required

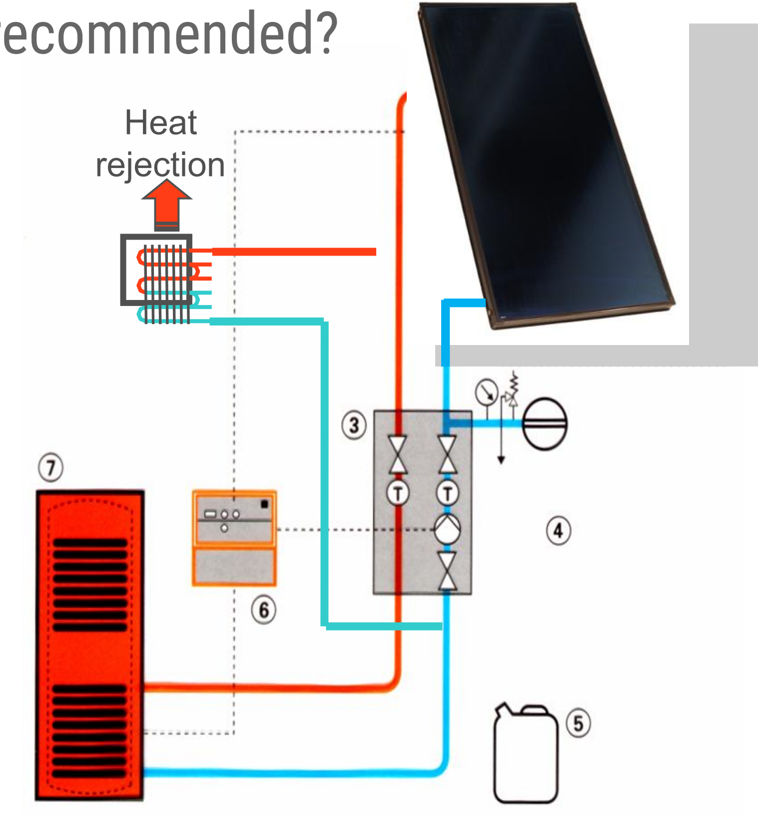


ThermProtect

Stagnation and overheating

When is a heat rejection circuit recommended?

- DHW - Space heating combi systems with no summer loads
- Evacuated Tube Collector Systems
- DHW systems with long unoccupied periods (schools, ski chalets, etc)
- DHW systems with intermittent loads
- Oversized systems
- Whenever simulation shows collector temperature spikes above maximum stability temperature of glycol



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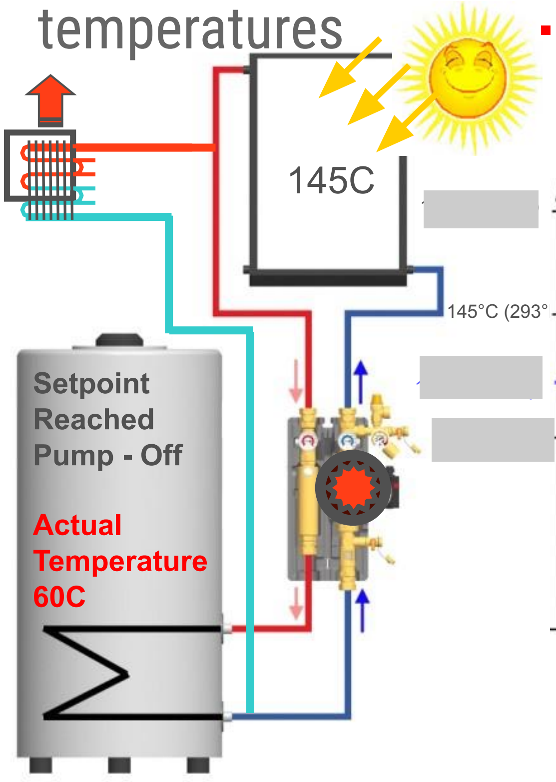
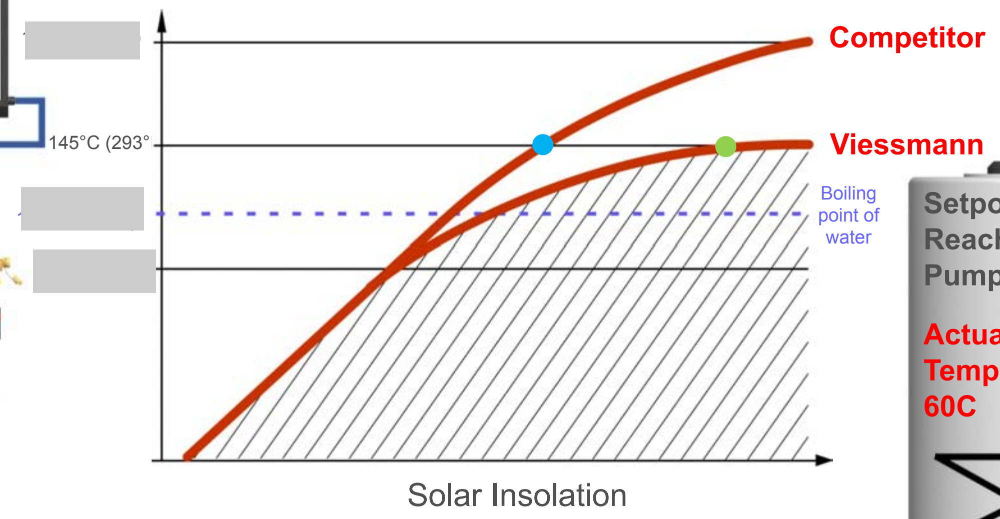
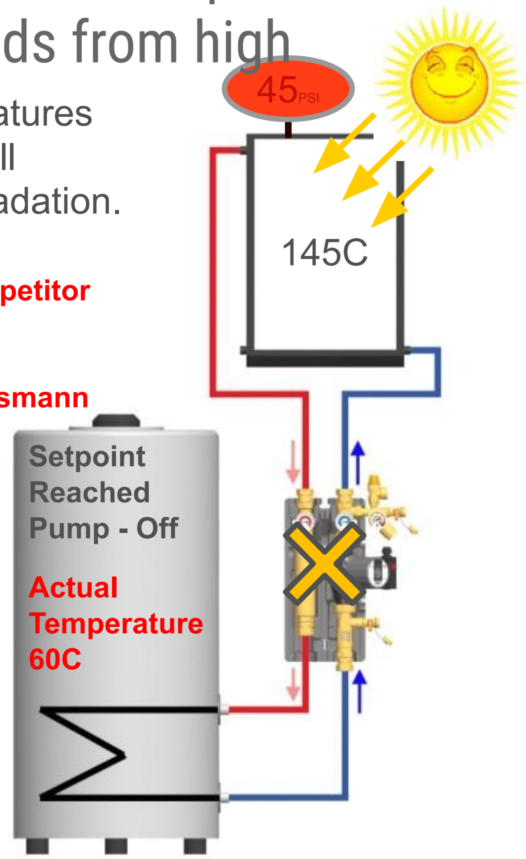
ThermProtect

Addition of Heat Dissipation, (Heat Dump), required to limit temperature in collectors without ThermProtect Coating to protect fluids from high temperatures

- Propylene glycol breaks down when temperatures exceed 170°C (338°F) thus ThermProtect will "*PROTECT*" the glycol from premature degradation.



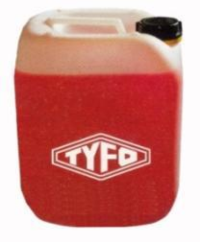




ThermProtect

Solar Stagnation

Stagnation Temperatures with ThermProtect Collectors

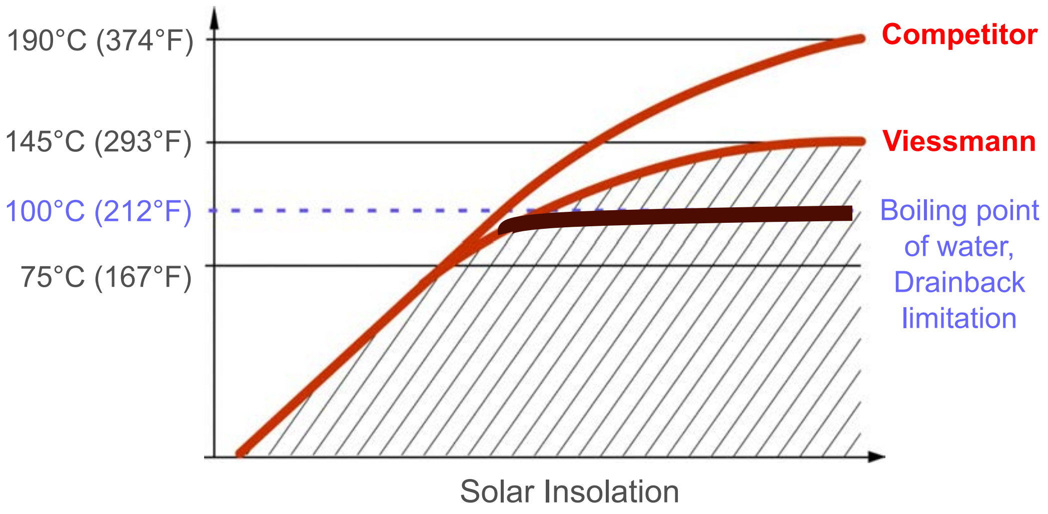


"Steamback" is not a problem if:

1. Expansion tank sized and pressurized properly
2. High temperature, reverse evaporable glycol is used, 145C or greater
3. High temperature components are used (pipe, insulation, etc)
4. ThermProtect Collector pressure set to 45PSI = No Steam Formation!!

ThermProtect

Vitosol 200-FM Flat Plate Collector ThermProtect – Switching Absorber Coating



Viessmann ThermProtect collectors increase system performance while reducing material/component costs, operational and maintenance downtime as experienced with competitors products.

- Competitors collectors overheat at higher or elevated temperatures of 190°C (374°F).
- Viessmann ThermProtect collectors overheat at much lower temperatures of 145°C (293°F).
- The ThermProtect absorber starts to change from an absorber to an emitter around ≈75°C (167°F).
- At temperatures above 75°C the absorber starts to reject heat from the absorber (similar to a radiator).
- Propylene glycol breaks down when temperatures exceed 170°C (338°F) thus ThermProtect will "*PROTECT*" the glycol from premature degradation.