Chapter:	Components
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Description:	Heat exchangers are used for transferring heat gained in collector array into demanded application (another heat-transfer fluid).
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Introduction

The heat exchanger unit provides the actual useful performance of the system. It is the sole component linking the solar heat to the district heating network. Therefore it is crucial for the overall plant efficiency to have a well performing heat exchanger with a properly balanced capacity flow on both sides as described below.

Heat transfer coefficient and temperature difference

The heat (Q) transferred from the solar collector loop (primary side) to the DH network (secondary side) is equal to the heat transfer coefficient of the heat exchanger (UA) times the temperature difference between primary and secondary side (ΔT) i.e. $Q = UA \cdot \Delta T$. The UA-value of the heat exchanger is provided by the heat exchanger manufacturer. If the UA is doubled, then ΔT can be halved and the heat delivered to the DH network will still be the same. By decreasing ΔT, the solar collector efficiency is increased as indicated in figure 7.4.1. η_{high} is the efficiency of the collectors if there had been no heat exchanger. η_{low} is the collector efficiency during operation. This indicates that ΔT should be minimized and the capacity compensated by a large heat transfer coefficient for the heat exchanger.

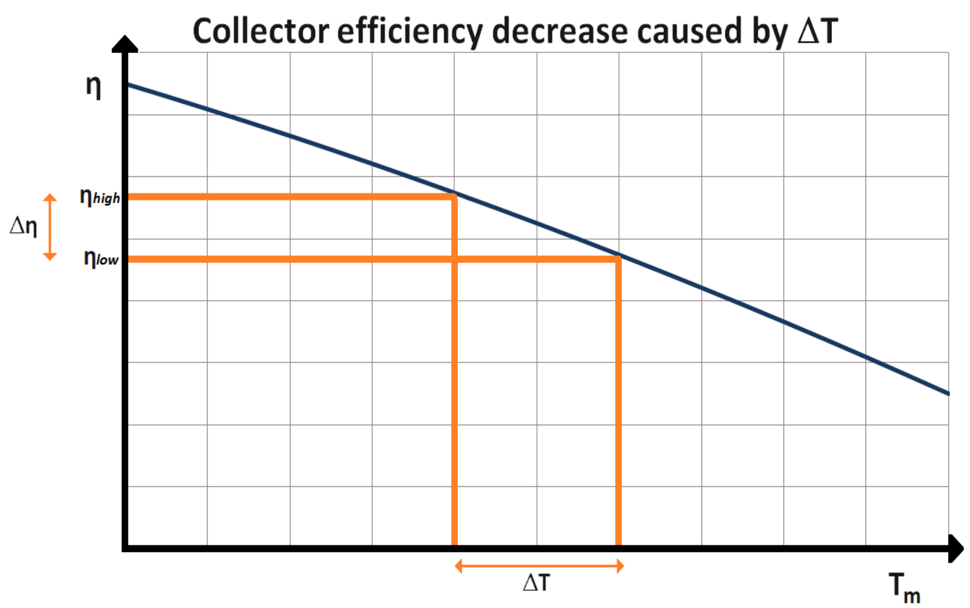

Fig. 7.4.1. Efficiency decrease caused by the temperature over the heat exchanger (difference between primary and secondary side temperature). (Source: PlanEnergi)

Heat exchangers can be sorted according to the several characteristics (e.g. parallel-flow / counter-flow, internal / external, shell and tube / plate). Normally a counter flow plate heat exchanger is used for large systems. For both parallel-flow and counter flow heat exchangers, the temperature difference is calculated as the logarithmic mean temperature difference (LMTD):

$$\Delta T_{mean} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} \qquad \text{(eq. 7.4.2)}^*$$

where

ΔT_1:	$T_{prim,in} - T_{sec,out}$	[K]
ΔT_2:	$T_{prim,out} - T_{sec,in}$	[K]

i.e. ΔT_1 is the temperature difference between the *inlet* temperature on the *primary* side and the *outlet* temperature on the *secondary* side, and ΔT_2 is the temperature difference between the *outlet* temperature on the *primary* side and the *inlet* temperature on the *secondary* side. This is indicated in figure 7.4.2 for counter-flow and parallel-flow heat exchangers.

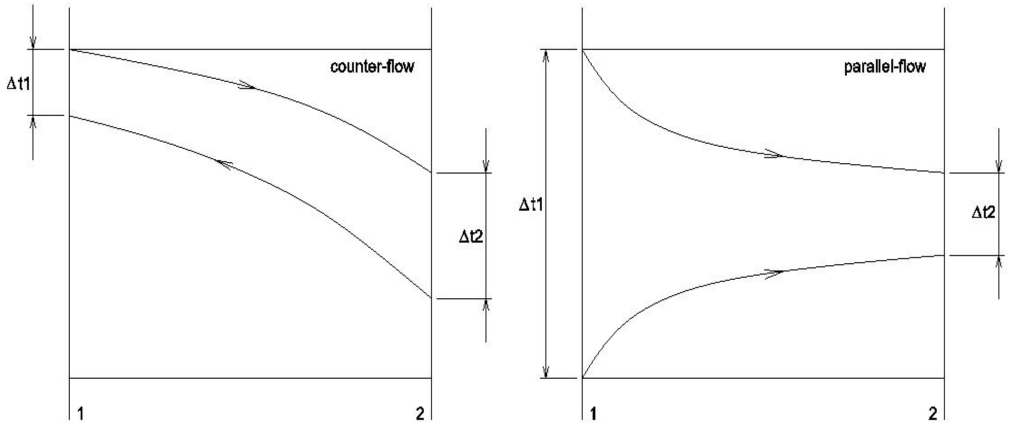

Fig. 7.4.2. Progression of temperatures in a parallel-flow and counter-flow heat exchanger [2].

Counter-flow plate heat exchangers are often used in large-scale solar systems. The exchanger is consisted of thin plates (mostly made of stainless steel), that are connected together to create a net of channels. Brazing or welding represents one way of connecting plates together. These methods symbolize the cheaper solution of plate heat exchangers manufacturing. The second possibility is to use supporting plates and screw exchanger together with bolts, nuts and gaskets. Main advantage of screwed exchangers is their ability to be demounted and cleaned properly. Clogging of exchanger has a significant influence on its

* *Note that if $\Delta T_1 = \Delta T_2$, then eq. 7.4.2 becomes obsolete and $\Delta T_{mean} = \Delta T_1 = \Delta T_2$.*

performance and pressure loss so dirt separators or dirt traps are used to prevent pollution of heat exchangers. Another way of preventing exchanger pollution lies in chemical treating of the heating water, before it is filled into the system.

Capacity flow

The capacity flow is the power which can be transferred to or from the liquid *per degree* (K) in difference between inlet and outlet temperature of the heat exchanger e.g. for the primary side (“prim”):

$$w_{prim} = \dot{V}_{prim} \cdot \rho_{prim} \cdot c_{p,prim} \qquad \text{(eq. 7.4.2)}$$

where

w_{prim}:	Capacity flow on primary side	[W/K]
$\dot{V}_{prim}$:	Flow rate on primary side of the heat exchanger	[m^3/s]†
ρ_{prim}:	Density of the solar collector fluid	[kg/m^3]
$c_{p,prim}$:	Heat capacity of solar collector fluid	[J/(kg·K)]

The capacity flow is calculated in the same way for the secondary side (“sec”) where water is the fluid.

It is important to keep the capacity flow rates as close as possible e.g. $0.95 \le w_{prim} / w_{sec} \le 1.05$. This way the upper and lower curve in figure 7.4.2 keep as close to each other as possible, resulting in the lowest average ΔT. This is ensured by controlling the flow rate according to the properties of the used fluids (e.g. water/glycol-mixture and water in the primary and secondary loop respectively).

Heat exchanger factor

It is seen in figure 7.4.1 that the more efficient the collector is (i.e. the slope of the collector efficiency curve is small), the less affected is the η by ΔT. This means that for high performance collectors the heat exchanger efficiency is less significant. The efficiency of transferred energy from the primary to the secondary side is expressed by the heat exchanger factor F’’’ which is equal to the ratio η_{low} / η_{high} based on the values from figure 7.4.1. In figure 7.4.3 is seen three examples of the heat exchanger factor as function of UA-value. The loss due to a too small heat exchanger can be considerable. If F’’’ is 0.9 it means that 10 % of the solar heat is wasted in the heat exchanger; hence the UA-value of the heat exchanger is important for the *total* SDH plant efficiency.

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† *Normally measured in m^3/h and divided by 3600 s/h in order to make the unit fit in the equation.*

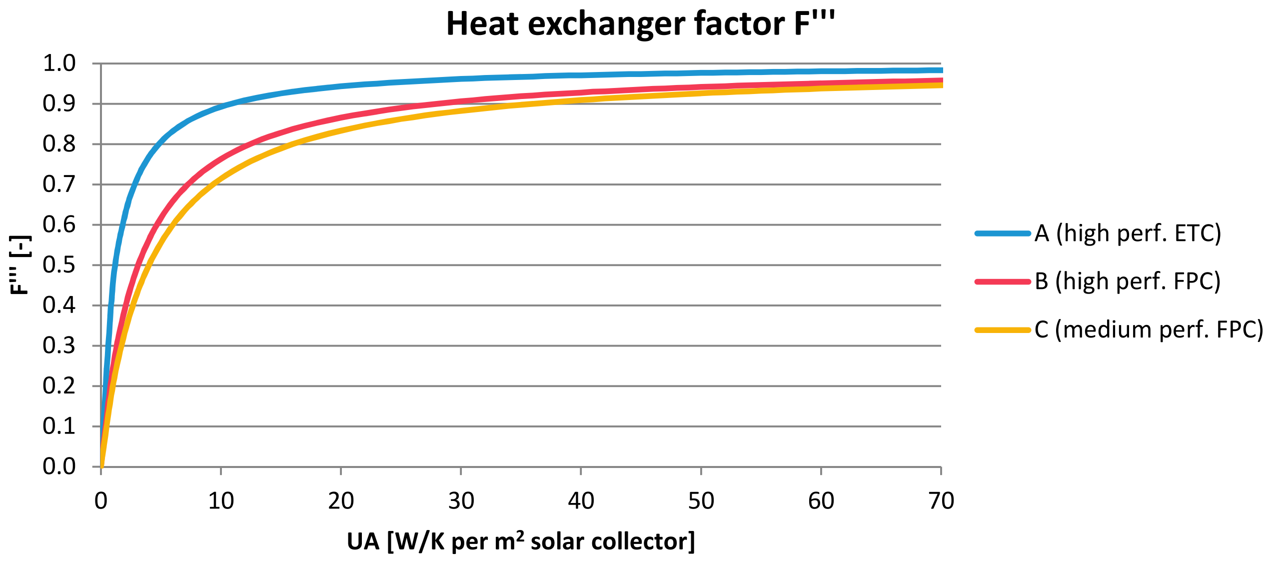

Fig. 7.4.3. Heat exchanger efficiency factor F''' as function of UA-value. (Source: PlanEnergi)

The following parameters are assumed: The heat capacity rate is assumed to be equal at both sides of the heat exchanger. Collector efficiency parameters as shown in table 7.1.1 (fact sheet 7.1), a glycol concentration of 40 wt%, 1 m^2 of collector area, ($T_{collector} – T_a$) = 50 K and a flow rate of 0.3 l/min per m^2.

Calculation of heat exchanger factor F'''

The influence of the UA-value can be expressed by means of the heat exchanger factor F''' [1], defined as:

$$F''' = \left(1 + \frac{F''}{\omega_c} \cdot \left(\varepsilon^{-1} - 1\right)\right)^{-1}$$

where

$$F'' = \left(1 - \exp\left(-\frac{1}{\omega_c}\right)\right) \cdot \omega_c \qquad \omega_c = \frac{\dot{m} \cdot c_p}{a_1 + a_2 \cdot (T_{collector} - T_a)} \qquad \varepsilon = \frac{\dfrac{UA}{\dot{m} \cdot c_p}}{\dfrac{UA}{\dot{m} \cdot c_p} + 1}$$

(when assuming equal heat capacity rate at both sides of the heat exchanger.)

F''' Heat exchanger factor [-]

$\dot{m}$	Mass flow in primary loop [kg/s]
c_p	Heat capacity of solar collector fluid [J/(kg·K)]
$T_{collector}$	Solar collector fluid temperature [°C]
T_a	Ambient temperature [°C]
a_1	1^{st} order collector heat loss coefficient [W/(m^2·K)]
a_2	2^{nd} order collector heat loss coefficient [W/(m^2·K^2)]
UA	Heat transfer coefficient in heat the exchanger [W/K].

A high UA value means low temperature difference between collector loop side and load side which decreases heat losses in collector end collector loop. A low UA value means high temperature difference between collector loop side and load side which increases the heat losses in collector end collector loop.

References

[1] The calculations are described in “Solar engineering of thermal processes” 4^{th} ed. by Duffie & Beckman section 6.7 and 10.2. In equation 10.2.3 (p. 424) F'_R/F_R is used instead of F’”.

[2] Solární tepelné soustavy (Solar thermal systems), MATUŠKA T. Společnost pro techniku prostředí – odborná sekce Alternativní zdroje energie, 2009.

The SDH fact sheets addresses both technical and non-technical issues, and provide state-of-the-art industry guidelines to which utilities can refer when considering/realizing SDH plants. For further information on Solar District Heating and the SDHtake-off project please visit www.solar-district-heating.eu.

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