

Procedure for Calculating Efficiency Equations and Ratings for Flat Plate Collectors
Sized Differently than a Tested Collector
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When several sizes of a given solar collector model are manufactured, usually only one must be tested to obtain certification of all of the sizes. The collectors must be identical, with regard to things that affect performance, in every respect except size. The other sizes of the same collector model can be certified using the procedure given here.

The unit aperture area optical gain and top/bottom loss coefficients of all of the sizes of a given collector model are assumed to be the same. The efficiency of the collectors sized differently than the tested collector is determined by taking into account the effect of size on the heat loss from the collector under these assumptions, as described below. SRCC imposes limits on the range over which this procedure can be used:

Size limits (gross dimensions):

- the new collector area can be no more than twice nor less than half the area of the tested collector
- the ratio of length to width (aspect ratio) of the new collector can be no less than half nor greater than twice the aspect ratio of the tested collector

Absorber limits:

- the spacing of the absorber tubes must be the same (within +/- 5%) in the new collector as in the tested collector
- the bond between the absorber plate and the tube must be the same in the new collector as in the tested collector
- the thickness of the absorber plate/fin must be the same (within +/- 5%) in the new collector as in the tested collector
- the absorber plate area in both sizes must be between 95% and 105% of the aperture area.

This procedure assumes that the test data on the collector includes the following for each data point:

- collector efficiency based on collector gross area
- collector inlet temperature
- ambient air temperature
- solar irradiance

This data is used to calculate the efficiency equation for a solar collector as:

$$\text{Efficiency} = Fr(\tau\alpha) - Fr U_L(T_i - T_a)/I$$

A quadratic form is also used to express collector efficiency, but that form is not treated explicitly here – the size adjustment procedure is the same. When the size of the collector changes, the loss coefficient based upon aperture area changes by some value (ΔU) because the ratio of the heat loss through the edge of the collector to the total heat loss changes:

$$\text{Efficiency} = Fr(\tau\alpha) - Fr (U_L + \Delta U) (T_i - T_a)/I$$

The difference between these two equations is:

$$\text{Change in efficiency} = Fr \Delta U (T_i - T_a)/I$$

where:

Fr = collector heat removal factor

ΔU = change in heat loss through the edge of the collector due to the different size.

$Fr(\tau\alpha)$ = intercept of the efficiency curve, which is a function of the transmissivity of the glazing and the absorptivity of the absorber coating.

U_L = collector overall heat loss coefficient

T_i = temperature of the fluid entering the collector

T_a = temperature of the air surrounding the collector

I = solar irradiance.

Therefore, to obtain the efficiency of the differently sized collector, each efficiency data point is modified to reflect the effect of the different size on heat loss from the collector:

$$\text{New efficiency} = \text{Tested efficiency} + Fr * \Delta U * (Ti - Ta)/I$$

The efficiency of the differently sized collector is determined as follows:

1. Multiply each efficiency data point by the ratio of the tested collector's gross to aperture area. This converts the efficiency to an aperture area basis.
2. Calculate the heat removal factor (Fr) for the tested collector from the following equations:

$$Fr = \frac{GC_p}{U_L} \left[1 - e^{-\left(\frac{U_L F'}{GC_p}\right)} \right] \quad (7.7.4 \text{ in Duffie \& Beckman})$$

$$F' = \frac{GC_p}{U_L} \left[\frac{\frac{1}{U_L}}{W \left[\frac{1}{U_L (D + (W - D)F)} + \frac{1}{C_b} + \frac{1}{\pi D_i h_{f,i}} \right]} \right] \quad (7.5.17 \text{ in Duffie \& Beckman})$$

$$F = \frac{\tanh\left(\sqrt{\frac{U_L}{k\delta}} \left(\frac{W - D}{2}\right)\right)}{\sqrt{\frac{U_L}{k\delta}} \left(\frac{W - D}{2}\right)} \quad (7.5.11 \text{ in Duffie \& Beckman})$$

$$h_{f,i} = 4.4 + 0.00172 \left[\frac{\left(\text{Re Pr} \frac{D_i}{L}\right)^{1.66}}{1 + .00281 \left(\text{Re Pr} \frac{D_i}{L}\right)^{1.29}} \right] \quad (\text{equation in CoDe Pro for laminar flow})$$

3. Calculate the effect of the change in collector size on the heat loss from the edge of the collector:

$$\Delta U = U_{\text{edge}} \left[\left(\frac{A_{\text{edge,new}}}{A_{\text{a,new}}} \right) - \left(\frac{A_{\text{edge,tested}}}{A_{\text{a,tested}}} \right) \right]$$

where U_{edge} = heat transfer coefficient of the side-wall insulation.

4. Calculate the efficiency of the new collector (for each data point):
New efficiency = Tested efficiency + Fr * ΔU * (Ti - Ta)/I
5. Multiply each efficiency data point by the ratio of the new collector's aperture to gross area. This converts the efficiency back to a gross area basis.
6. Recalculate the efficiency equations and OG-100 ratings using the new data set for efficiency and the procedures outlined in SRCC document RM-1.