Solution to Exercise Nr. 8

Design of a CPC for a Solar Furnace

1.

$$C_{max} = \rho_{heliostat} \cdot \rho_{concentrator} \frac{sin^2 \phi_{rim}}{(\theta + \Delta_{error})^2} \rightarrow \Delta_{error} = 1000 \cdot \sqrt{\frac{0.85 \cdot 0.85 \cdot sin^2 45^o}{5530}} - 4.65 = 3.43\, mrad$$

2. Losses in power and concentration are due to geometrical imperfections (such as heliostat flatness, facets misalignment, structural bending and deformations, and a segmented approximation to the exact parabolic profile), optical imperfections (such as the reflectivity and specularity of the mirrors and glass absorption), shading effects (such as shading caused by the venetian shutter, receiver, and the non-reflective space or frame around each mirror facet), and tracking imperfections.

3. Fig. 2, for aperture diameter 5 cm: $\tilde{C}$ = 4200.

$$T_{stagnation} = \left(\frac{I \cdot \tilde{C}}{\sigma} \right)^{0.25} = \left(\frac{1000 W/m^2 \cdot 4200}{5.67 \cdot 10^{-8}\ W/(m^2 K^4)} \right)^{0.25} = 2934\, K$$

4.

$$T_{optimal}^5 - (0.75 T_L) T_{optimal}^4 - \left(\frac{T_L I \tilde{C}}{4\sigma} \right) = 0 \rightarrow T_{optimal} \approx 1457\, K$$

5.

Φ	45º	30º
r_{out}	2.5 cm	2.5 cm
$C_{CPC} = sin^{-2} \Phi$	2	4
$r_{in} = r_{out} \cdot (C_{CPC})^{0.5}$	3.54 cm	5.0 cm
$L = (r_{in} + r_{out}) \cdot \cot \Phi_{rim}$	6.04 cm	13.0 cm

6.

Φ	45º	30º
C_{CPC}	2	4
r_{in}	3.54 cm	5.0 cm
Q_{solar} (Fig 2)	≈14 kW	≈20 kW
$\tilde{\tilde{C}}$ (Fig 2)	≈3500	≈2600
$\eta_{Acceptance}$ (For Φ_{rim} = 45º)	100%	41.8%
CPC reflectivity ρ	0.9	0.9
Total Power = $Q_{solar} \cdot \rho \cdot \eta_{Acceptance}$	≈12.6 kW	≈7.6 kW
Total Mean Concentration = $\tilde{\tilde{C}} \cdot C_{CPC} \cdot \rho \cdot \eta_{Acceptance}$	≈6300	≈3900

7.

Φ	45º	30º
Total Mean Concentration = $\tilde{\tilde{C}} \cdot C_{CPC} \cdot \rho \cdot \eta_{Acceptance}$	≈6300	≈3900
$T_{stagnation}$	3247 K	2880 K
$T_{optimal}$	1576 K	1434 K