PERGAMON

Energy Conversion and Management 42 (2001) 1379–1399

ENERGY CONVERSION & MANAGEMENT

www.elsevier.com/locate/enconman

Development and performance analysis of compound parabolic solar concentrators with reduced gap losses – oversized reflector

R. Oommen [a,*], S. Jayaraman [b]

[a] *Department of Physics, Avinashilingam University, Coimbatore, Tamil Nadu 641043, India*
[b] *SRK Vidyalaya College of Arts & Science, Coimbatore, Tamil Nadu 641020, India*

Received 23 February 2000; accepted 9 September 2000

Abstract

A severe energy shortage already exists in many parts of the developing world. In an attempt to find a technical solution, several solar energy collection technologies have been developed. A system has been designed to use compound parabolic concentrating collectors to collect solar energy and to generate steam. A compound parabolic concentrator (CPC) profile with oversized reflector and thereby reduced gap losses was designed with a half-acceptance angle of 23.5° for a tubular absorber of OD 19 mm. Five troughs fabricated with a fiberglass substrate pasted over with UV stabilized self-adhesive aluminized polyester foil having high specular reflectivity joined together side by side make the CPC module with aperture area of 0.72 m^2. Copper tubes coated with NALSUN selective coatings and enclosed by borosilicate glass envelopes act as absorbers. The reflector–absorber assembly placed in a single glazed glass wool insulated wooden box forms the CPC collector. Using water as heat transfer fluid, efficiency tests were conducted with different inlet temperatures. Even at high temperature, the system operates with a reasonably high efficiency of 50%. In situ steam generation testing was also conducted. The fabricated CPC collector was used for steam cooking by connecting it to a pressure cooker. Cooking tests were conducted and the results are compared with earlier works. This cooker unites the characteristics of reflector cookers, steam cookers, pressure cookers and heat accumulating solar cookers. The fabricated CPC can be of immense and wide spread use for rural applications, such as water heating, steam cooking and sterilization.

* Corresponding author. Tel.: +91-422-443-456; fax: +91-422-446-116.
E-mail address: kmagm@vsnl.com (R. Oommen).

PII: S0196-8904(00)00113-8

Nomenclature

A	area
CPC	compound parabolic concentrator
CR	concentration ratio
C_w	specific heat of water
F	heat transfer factor
g	gap thickness
h	height
I	solar irradiance
L	length, latent heat of vaporization
m	mass
$\dot{m}$	mass flow rate
$\langle n \rangle$	average number of reflections
p	gap loss factor
q	rate of energy
r	radius
r_1	radius of receiver
r_2	radius of envelope
T	temperature
t	time
U_L	heat loss coefficient

Greeks

α	absorptance
δ	gap thickness
ε	infrared emittance
η	efficiency
ρ	reflectance, density, length of tangent
τ	transmittance
θ_A	half-acceptance angle
θ_{in}	incident angle
ΔT	difference in temperature

Subscripts

a	ambient
abs	absorber
av	average
b	beam
c	cover
d	diffuse
e	envelope
eff	effective
end	end loss
f	fluid
i	inlet, inner, instantaneous
m	mirror
o	outlet, outer, optical
r	receiver, radiation
ref	reflection
u	useful

1. Introduction

A CPC for a flat absorber is one which consists of curved segments, which are parts of two parabolas. Many improvements in the design and performance of the CPC collector have been made since its invention in 1974. The CPC reflector profile for a tubular absorber is such that the reflector touches the absorber at the cusp region. This results in conductive heat losses. So, a gap between the tubular absorber and the reflector has to be created to prevent this conduction heat loss from absorber to metallic reflector and also for providing a glass envelope around the absorber, which will improve the thermal efficiency of the CPC module at high temperatures. However, the gap between the absorber and the envelope leads to losses of the incident light on the absorber, called ‘gap losses’. So, a compromise between optical and thermal performance must be made. Several modifications of the basic CPC design were suggested for the provision of gap. Winston [1] proposed a reflector design which preserved the ideal flux concentration on the absorber of radius r_1, surrounded by a glass envelope of radius r_2, at the expense of slightly over sizing the reflector. This design maintains maximal concentration at the cost of optical losses.