ABSTRACT

Low-flow solar hot water heating systems employ flow rates on the order of 1/5 to 1/10 of the conventional flow. Low-flow systems are of interest because the reduced flow rate allows smaller diameter tubing, which is less costly to install. Further, low-flow systems result in increased tank stratification. Lower collector inlet temperatures are achieved through stratification and the useful energy produced by the collector is increased.

The disadvantage of low-flow systems is the collector heat removal factor, F_R, decreases with decreasing flow rate. A serpentine collector has the potential to perform better than a conventional header-riser collector in low-flow systems due to the earlier onset of turbulent flow which enhances the internal heat transfer coefficient. The onset of turbulent flow is a function of the tube diameter and flow rate per tube.

Many solar domestic hot water systems require an auxiliary electric source to operate a pump in order to circulate fluid through the solar collector. A photovoltaic driven pump can be used to replace the standard electrical pump. PV driven pumps provide an ideal means of controlling the flow rate, as pumps will only circulate fluid when there is sufficient radiation. The reduction of parasitic pumping power can also reduce on-peak utility demand. The PV pump, if adequately designed, decreases the system performance by a negligible amount.

There has been some confusion as to whether optimum flow rates exist in a solar domestic hot water system utilizing a heat exchanger between the collector and the storage tank, as commonly employed for freeze protection. It was found that there exists thermal optimum or at least economical optimum flow rates when it is considered that low flow rates incur less hydraulic costs. Peak performance was always found to occur when the heat exchanger tank-side flow rate was approximately equal to the average load flow rate. For low collector-side flow rates, a small deviation from the optimum flow rate will dramatically effect system performance. However, system performance is insensitive to flow rate for high collector-side flow rates.

Antifreeze solutions have temperature dependent properties such as density and specific heat. The effect of large temperature dependent property variations experienced by ethylene glycol and propylene glycol affect the optimum flow rate through the collector-side of the heat exchanger. The increased viscosity of the glycol at low temperatures impedes the onset of turbulence, which is detrimental to the heat exchanger UA.

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Some look at things as they are and ask "why?"
I dream for things that never were and ask "why not?"

Author unknown

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NOMENCLATURE

a	thermal voltage	V
A_c	collector area	m^2
C_b	contact resistance	W/m.K
Cp	specific heat	J/kg.K
D	nominal pipe diameter	m
D_i	inner diameter of tube	m
D_o	outer diameter	m
f	friction factor	
F'	collector efficiency factor	
F_R	collector heat removal factor	
g	gravitational acceleration	m/s^2
G_T	solar radiation	W/m^2
h	head	m
h_{fi}	internal heat transfer coefficient	W/m^2K
h_i	heat transfer coefficient of inner fluid	$W/m^2.K$
h_o	heat transfer coefficient of outer fluid	$W/m^2.K$
I	current	A
I_D	diode current	A
I_L	light current	A
I_{mp}	maximum power point current	A
I_o	dark current	A
I_{sc}	short circuit current	A
I_{sh}	shunt resistance current	A

k	conductivity	W/m.K
K	minor loss coefficient	
L	length	m
$\dot{m}$	flow rate	kg/s
N	number of tubes in parallel in a serpentine collector	
N_G	number of glass covers	
N_s	number of cells in series in a module	
NTU	number of transfer units	
Nu	Nusselt number	
P	power	W
P	pressure drop	Pa
Pr	Prandtl number	
Q	flow	gpm
$Q_{auxiliary}$	auxiliary heat	W
Q_{hx}	heat exchanger heat transfer	W
Q_{load}	load	W
Q_u	solar collector useful energy	W
R	resistance	m.K/W
Re	Reynolds number	
R_s	series resistance	Ω
R_{sh}	shunt resistance	Ω
S_L	longitudinal pitch of tube bank	m
S_T	transverse pitch of tube bank	m
SF	solar fraction	
T_a	ambient temperature	K
T_b	temperature at the base of the plate	K
T_c	cell temperature	K

T_{ci}	inlet fluid temperature of cold fluid	K
T_{hi}	inlet temperature of hot fluid	K
T_i	temperature of collector inlet fluid	K
T_o	fluid outlet temperature	K
T_{pm}	plate mean temperature	K
U_{back}	collector back loss coefficient	$W/m^2.K$
U_{edge}	collector edge loss coefficient	$W/m^2.K$
U_L	overall collector loss coefficient	$W/m^2.K$
U_{top}	collector top loss coefficient	$W/m^2.K$
$\vec{v}$	velocity	m/s
V	voltage	V
V_{mp}	maximum power point voltage	V
V_{oc}	open circuit voltage	V
W	tube spacing	m

<u>Symbols</u>

d	absorber plate thickness	m
b	collector tilt	degrees
r	density	kg/m^3
e	heat exchanger effectiveness	
e	material bandgap energy	eV
$(t a)_{av}$	average transmission-absorption product	
e_g	glass emittance	
h_i	collector efficiency	
$m_{I,sc}$	temperature coefficient for short circuit current	A/K
e_p	plate emittance	
$m_{V,oc}$	temperature coefficient for open circuit voltage	V/K