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Towards making solar water heating technology feasible—the polymer solar collector approach

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Abstract

The idea of developing new, innovative, low-cost solar collectors for large solar system design is emphasized towards making this technology feasible. The design principle of new low-cost modular solar collectors made of recycled low-cost polymer materials is presented, and their efficiency factor and overall loss coefficient is estimated for the low thermal conductivity materials involved. Based on derived results and system components assumptions, long-term performance investigations were conducted for typical load and meteorological conditions corresponding to a sunny Mediterranean country. Results from those investigations, combined with the estimated cost of proposed collectors and current costs of conventional collectors, were employed for comparative evaluation of the payback period, which indicates the importance of design innovation for the commitment-based promotion of large solar systems technology. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Solar heating; Polymer collectors; System design innovation

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1. Introduction

Although, owing to environmental reasons, the need for deep penetration of renewable energies in the world energy scene is today more urgent than ever, it is surprising that even the most obvious technologies, like solar water heating, are not yet considered completely mature to compete with conventional energy. Apart from recently occurring surprisingly impressive

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Nomenclature

A	area (m^2)
b	plate thickness (m)
c	yearly cost ($/y)
C	initial cost ($)
c_p	heat capacity (J/kgC)
d	yearly benefits ($/y)
e	escalation rate (%)
F'	collector efficiency factor (–)
F_R	collector heat removal factor (–)
H	defined as k_p/b (W/m^{2}C)
i	interest rate (%)
k	thermal conductivity (J/mC)
$\dot{M}$	mass flow rate (kg/m^2 s)
P	payback period (years)
q	heat rate (W/m^2)
r	discount rate (%)
S	energy absorbed (W/m^2)
T	temperature (C)
U	heat loss coefficient (W/m^{2}C)

Greek letters

ε	unit area cost ($/m^2)
λ	fixed cost component ($)
$\tau\alpha$	transmittance–absorbtance product

Subscripts

a	ambient
b	base
c	collector
f	fluid
i	inlet
L	overall loss
n	normal
p	plate
t	top
u	useful

developments, promotion of solar heating technology is mainly inhibited by the cost of conventional energy which has been stabilized at relatively low levels during the last decade. Today, it appears that earlier State incentives and tax relief policies are being gradually replaced by schemes which are more compatible to a completely free market environment.

These are the commitment-based schemes, such as guaranteed performance and payback through energy savings.

The first scheme is based on the provision of a minimum performance guarantee to the solar system owner which, if not satisfied, will impose a penalty payment on the system manufacturer–designer. The second scheme, being relevant to leasing and third-party financing, relies in principle on a contract for provision of the complete package of design, construction, financing and maintenance services for a solar heating plant which is leased by an energy services company to a user who contracts to purchase measured solar energy at a beneficial cost. Therefore, the leased system can be paid off through the measured energy savings, transferring in this way all technical and economic risks from the user to the specialized solar energy services company, which has every incentive to proceed to low-cost innovative design and efficient maintenance services in order to achieve the earliest payback [1]. Thus payback time becomes a decisive parameter for implementation of this promotion scheme, since it determines how economically attractive the contract would be for both parties.

As the cost of solar heating plants is dominated by the cost of the collector subsystem, it becomes clear that development of a low-cost collector subsystem would very possibly lead to the earliest possible payback of the initial investment, something which will appreciably improve the competitiveness and promotion of this technology in a completely free market environment.

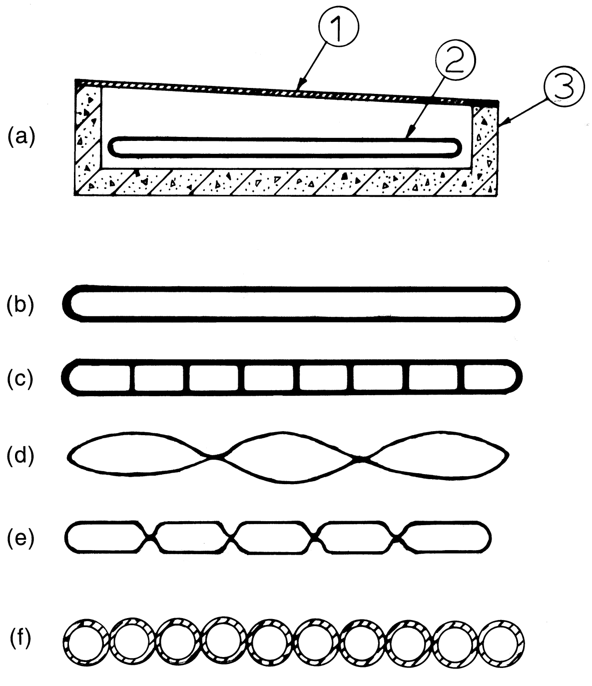

Fig. 1. The cross-section of the polymer collector (a) with its main components the collector container (3), polymer absorber (2) and top glass pane glazing (1). In (b) to (f) typical designs of polymer absorbers, (b) parallel polymer plate, (c) rib connected parallel plate, (d) seamed plastic foil absorber, (e) butyl rubber absorber, (f) polymer tube absorber.

It has been long established that significant cost reduction would not be expected using commonly employed collector design and materials. Earlier and more recent investigations have shown the significant potential of polymer materials for the design and mass fabrication of low-cost solar collectors [2–4]. Simple plastic film integral collector storage systems have been earlier proposed as low-cost solar water heaters [5]. The extensive use of recyclable polymer collector parts for in situ assembly of large modular collector arrays allows not only a significant cost reduction of the collector subsystem in solar heating plants but can also minimize the associated plumbing and drastically limit the possibility of corrosion due to electrochemical effects, something which leads to annual system cost reduction.

The purpose of the present work is to investigate the possibility of using simple low-cost solar collectors in large solar water heating plants. An analysis is developed for investigation of the effects of the low thermal conductance of polymer absorber plates on the efficiency and loss factor of the collector. The modified parameters are employed for investigation of the long-term performance of the proposed heating plant. Comparable unit area cost estimates are employed for calculation of the payback period, which becomes now a decisive parameter for the investment.

2. Collector design and analysis

The collector is composed, as shown in Fig. 1(a), of the collector glazing (1), polymer absorber (2) and collector enclosure (3). The collector enclosure is made of rigid, in situ assembled, polymer prefabricated modular parts. They are made of hard structural foam thermal insulation material usually produced by gas dispersion into a polymer melt during processing to produce a hermetic cellular core structure.

The polymer absorber is sitting inside the collector container and, in its simplest form, is composed of two dark parallel polymer plates through which a heat transfer fluid flows to remove the heat transferred through the top polymer plate where the incoming solar radiation is absorbed.

It is widely known that a serious disadvantage of polymer glazings in solar collector design is the strong weathering effects and degradation under extended exposure to UV radiation. Also, most polymer glazing materials are partially transparent to the near and far IR spectrum, something which leads sometimes to excessively high long-wavelength radiation losses directly from the absorber plate to the sky. As compared to polymers, glass is an excellent glazing material which is not only completely stable but, owing to its superior spectral characteristics, offers adequate UV protection against ageing of the polymer absorber underneath, being at the same time completely opaque to the IR part of the spectrum up to about 2.8 μm. The glass panes are fixed at the rim of the enclosure and are sealed with a silicone-based sealant as shown in Fig. 1(a).

Another serious disadvantage of using polymer materials in collector absorber design is their low thermal conductivity as compared to metal absorbers. Therefore, any effort towards maintaining heat flow paths as short as possible between the absorbing surface and the heat transfer fluid would lead to a substantial corresponding increase of thermal conductance, something which tends to balance the poor thermal conductivity of most polymers. This explains the current widespread design trend of polymer absorbers to maintain maximum contact between the absorbing surface and the heat transfer fluid, the so-called 'fully wetted' absorber design, using as thin as possible polymer absorber plates. The simplest and most straightforward absorber design is shown in Fig. 1(b), in which a heat transfer fluid stream flows between two dark parallel polymer plates at the top surface of which solar radiation is admitted.

Rib connected parallel plate absorber design is usually employed to withstand the developed hydrostatic forces by the fluid column within the collector as shown in Fig. 1(c), splitting the heat transfer fluid flow into a number of parallel streams. In this case, the heat transfer enhancement due to the ribbing is considered negligible owing to the small thermal conductivity of the associated materials.

In a slightly modified absorber design shown in Fig. 1(d), the pair of parallel absorber plates may possibly be replaced by thin polymer films seamed together in a direction parallel to the fluid flow. The number of parallel heat transfer flow streams would be proportional to the number of seams per unit width of the absorber. Although the use of films is more preferable than the use of polymer plates with lower thermal conductance and since seaming is sometimes desirable to improve absorber rigidity, it tends anyway to reduce the contact area between the

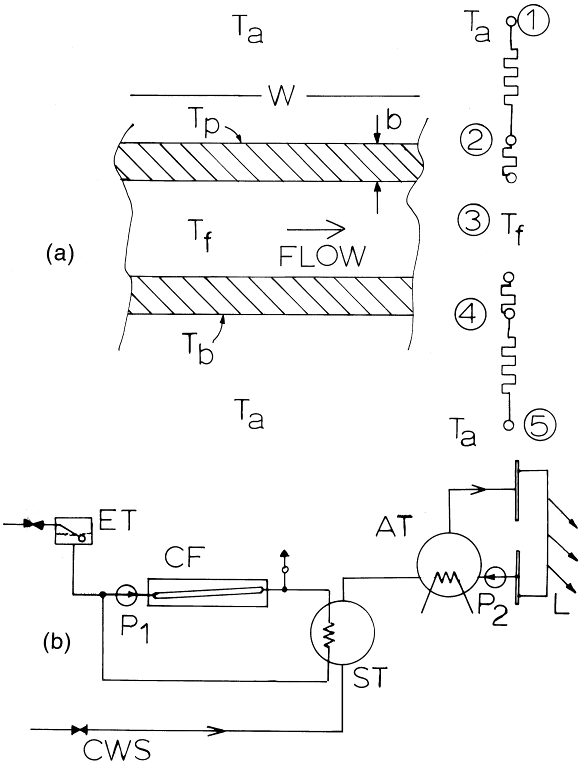

Fig. 2. The parallel polymer plate absorber model (a). The solar heating plant in (b), with the collector field array (CF), solar tanks (ST) in preheating mode with afterheating tanks (AT), distribution network with load (L) and expansion tank (ET). P_1 and P_2 the closed circuit solar and distribution network pumps, respectively.

absorber surface and the heat transfer fluid, something which becomes even more obvious for other familiar absorber designs as the butyl rubber bag or even absorbers composed of long polymer tubes attached to thick header tubes, as shown in Fig. 1(e) and (f), respectively.

The useful heat gain of a solar collector can simply be expressed as a function of a mean absorber plate temperature. To overcome the difficulty of using mean plate temperature, two additional dimensionless factors, the collector efficiency and heat removal factor F' and F_R are defined, respectively, in the familiar Hottel–Willier–Bliss model to allow reference into more easily accessible parameters, the local fluid temperature T_f and the fluid inlet temperature T_i, respectively. However, their analytical derivation, which is extensively covered in the literature [6], refers to the familiar metal sheet and tube design of the solar collector absorber, and it is based on the assumption of negligible temperature gradient through the absorber metal sheet.

Although this assumption is adequately justified in practice for metal absorbers owing to their large thermal conductivity and small thickness, it is no longer valid for polymer absorbers with their appreciably lower thermal conductivity, and therefore, it would be necessary to take into consideration the finite thermal conductance of polymer plates in the Hottel–Willier–Bliss model. In Fig. 2(a), the model of a simple polymer absorber of two parallel polymer plates of thickness b is shown, between which a heat transfer fluid stream flows at a uniform temperature T_f.

Assuming one-dimensional heat flow perpendicular to the absorber plate (negligible edge losses), something which is very well justified especially for large collector arrays, the steady state heat balance equation for node 2 of the thermal network is

$$S - U_t(T_p - T_a) - (k_p/b)(T_p - T_f) = 0 \tag{1}$$

with k_p being the thermal conductivity of the polymer plate. The corresponding heat balance equations for nodes 2 and 3, respectively, are

$$(k_p/b)(T_f - T_b) - U_b(T_b - T_a) = 0 \tag{2}$$

$$(k_p/b)(T_p - T_f) - q_u - (k_p/b)(T_f - T_b) = 0 \tag{3}$$

with U_t and U_b being the top and base loss coefficients and q being the useful heat gain of the collector. Eliminating T_b from Eqs. (2) and (3), it is derived that

$$T_p = 2T_f - \frac{(k_p/bU_b)}{1 + (k_p/bU_b)} \times T_f - \frac{1}{1 + (k_p/bU_b)} \times T_a + q_u/(k_p/b) \tag{4}$$

and upon substitution of T_p from Eq. (4) into Eq. (1), it is derived that

$$q_u = F'\left[S - U_L(T_f - T_a)\right] \tag{5}$$

with,

$$F' = \frac{H/U_b}{H/U_b + U_t/U_b} = 1/(1 + U_t/H) \tag{6}$$

and

$$U_L = U_t\left(1 + \frac{1}{1 + (H/U_b)}\right) + U_b\left(1 - \frac{1}{1 + (H/U_b)}\right) \tag{7}$$

for

$$H = k_p/b. \tag{8}$$

Then, the collector unit area useful heat gain can be easily derived as a function of the fluid inlet temperature $T_{f,i}$, assuming that the unit area useful heat gain calculated from Eq. (5) is transferred to the heat removal fluid entering the collector at temperature $T_{f,i}$. It is derived that

$$q_u = F_R\left[S - U_L(T_{f,i} - T_a)\right] \tag{9}$$

where

$$F_R = \frac{\dot{M}c_p}{A_c U_L} \times \left[1 - e^{-A_c F' U_L/\dot{M}c_p}\right] \tag{10}$$

with the parameters F' and U_L being given by expressions (6) and (7), respectively.

It can be seen from expressions (6) and (8) that reduction of the polymer absorber plate thickness leads to reduction of the ratio (U_t/H) and subsequent increase of the numerical value of F', as expected, toward unity.

At the same time, an increase of the plate thickness for a fixed back loss coefficient leads to large numerical values of (H/U_b) and significant reduction of the quantity $[1 + (H/U_b)]^{-1}$, something which leads expression (7) to its more conventional form as a sum of top and back loss coefficients.

3. Theoretical modelling and long-term system performance

Collectors of the proposed design are readily offered for horizontal installation and can be installed to retrofit heating plants in existing or new buildings. They can also be installed with a slight mechanical support at any desirable slope to optimise long-term performance, although it has been found in practice that a few per cent sacrifice of system performance is justified sometimes by the possibility of proper integration of large collector fields on the roof of commercial or hotel buildings in architecturally protected regions like holiday resorts, where heating loads are strongly seasonal and perfectly matched with ordinary seasonal occupancy patterns.

The closed circuit loop of the solar collector field is introduced between the conventional water heating plant (AT) shown in Fig. 2(b) and the cold water supply line (CWS) through the installation of solar pre-heating tank(s) (ST). Since the solar collector field (CF) and solar tank(s) (ST) are connected in the pre-heating mode, they can easily be temporarily isolated, for any reason, from the conventional heating plant by using by-pass lines. Ordinary thermostatic control is required for operation of the closed circuit collector flow loop and hot water distribution pumps P_1 and P_2, respectively. The use of an expansion tank (ET) at the collector closed circuit loop is essential in order to ensure the necessary static pressure for operation and avoid possible stagnation conditions during operation owing to leakage.

There are a considerable number of theoretical long-term performance prediction models of a wide complexity level appearing in the literature, among which TRNSYS and f-chart are the most widely known. Although the first is a versatile simulation model of undisputable accuracy and flexibility, its use is relatively limited owing to the cost and the considerable familiarity required for the average user. The latter is a user-friendly simplified correlation algorithm, derived under many restrictive assumptions from the first, and was proved to be of an adequate level of accuracy although lacking in flexibility.

Aiming to bridge the considerable gap between those two, a simple, accurate and flexible dynamic simulation model was recently developed for long-term performance investigations. The model is based on the sequential solution of a system of heat balance equations representing all system components, through hourly time steps for the entire time domain of each month of the year. The extensive hourly meteorological data required for the calculations are generated by the computer model from corresponding long-term data for Athens, Greece. These data are easily introduced in the form of long-term daily average solar radiation and daily average ambient temperature, and they are subsequently split into direct and diffuse hourly data. The model, which was previously presented in [7], allows relaxation of several assumptions and restrictions imposed by several simplified models and offers results in very close agreement with those from the f-chart method. This model was employed for long-term performance investigations of the solar water heating system shown in Fig. 2(b) for the collectors of the proposed design.

Performance predictions, as derived from theoretical modelling investigations, are usually based on idealized assumptions, referring to component characteristics of the mechanical installation, continuous full load operation of the system under the size and regularity patterns of given seasonal, daily and hourly distribution profiles and uninterrupted operation based on provision of an ideal level of maintenance services.

However, practically, neither the size or the time distribution profile of load patterns are always regular, nor are weather conditions always close to ‘typical’, while it is always impossible to account for effects like the time variation of component characteristics due to ageing and degradation or accumulation of dirt owing to improper cleaning of optical surfaces. These effects can possibly explain the systematic deviation observed between theoretical predictions and measurements from monitored plants [8,9], which may be sometimes substantial. Furthermore, unforeseeable effects, like major component failures, which are unavoidable even under the provision of good preventive maintenance services, may probably reduce the degree of system exploitation and yearly average performance. Similarly, operation under fractional or no load conditions, as happens for example during summer holidays in residential buildings, may also remarkably diminish the yearly energy savings and the exploitation level of the investment in the period of the year with the maximum available solar radiation. Deviations are sometimes remarkable depending on the selection of appropriate modelling assumptions and operating conditions as close to the actual as possible. In order to take into consideration such unpredictable events, it was decided to introduce a reduction factor for the results from the theoretical predictions which determines a certain safety margin for the payback calculations.

Assuming that the collector field is composed of large horizontal collector arrays of 50 m^2 total aperture area, the long-term performance prediction was determined for the system configuration shown in Fig. 2(b). The solar preheating (ST) and afterheating (AT) tank(s) are assumed to be fully mixed with capacities of 2.5 m^3 and 1.5 m^3, respectively and the system is assumed to supply the daily load with 5000 litres of hot water at 50°C, with a load demand profile similar to Mutch for negligible distribution network losses and finite heat losses for both tanks.

For an average thermal conductivity of absorber polymer plate of about 0.2 W/mC and a typical thickness of about 2.0 mm, the parameter H becomes typically 10 W/m^2C. For top and base loss coefficients of about $U_t = 5$ and $U_b = 2$ W/m^2C, respectively, for the collectors under consideration, the estimated overall loss coefficient according to expression (7) is $U_L = 7.06$ W/m^2C, something which is only slightly higher than the value predicted by the familiar expression $U_L = U_t + U_b = 7$ W/m^2C.

At the same time, the estimated value for the parameter F' from expression (6) is about $F' = 0.94$, something which, for a mass flow rate of 0.015 kg/m^2 s, leads to a collector heat removal factor from expression (10) of about $F_R = 0.89$. Assuming a typical figure of about $(\tau\alpha)_n = 0.8$ for a normal transmittance–absorbtance product for the given glazing system, the following collector parameters were derived ($F_R(\tau\alpha)_n$, F_R U_L) = (0.71, 6.3). These parameters were introduced in the theoretical model for long-term performance prediction investigations.

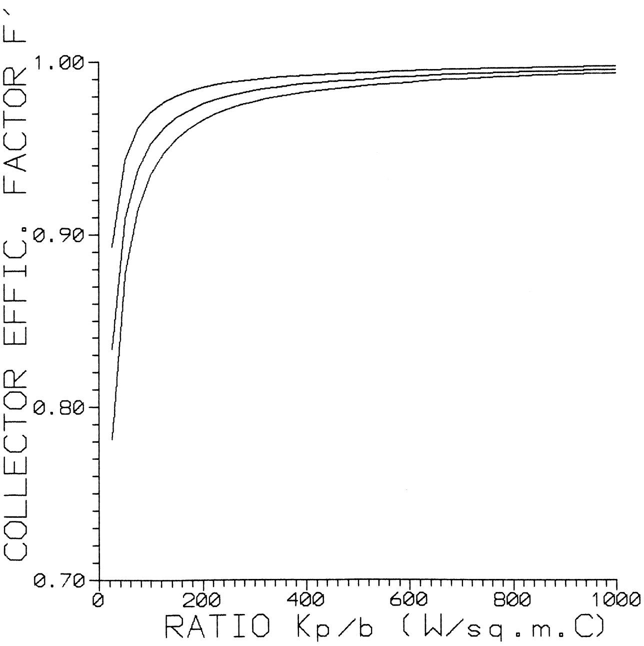

Fig. 3. Calculated collector efficiency factor F' as a function of $H = k_p/b$ for the top loss coefficient as a parameter. The topmost line corresponds to $U_t = 3$, while the following two underneath are 5 and 7 W/m^2C.

4. Results and discussion

In Fig. 3, the collector efficiency factor, as derived from expression (6), is plotted as a function of the parameter $H = k_p/b$, which now becomes an important design parameter for collectors with polymer plate absorbers, with the top loss coefficient U_t as parameter. The topmost curve corresponds to parameter $U_t = 3$ W/m^{2}C, and the following two underneath, to 5 and 7 W/m^{2}C. Since the thermal conductivity of most polymer materials varies slightly around 0.2 W/m^{2}C, H becomes considerably high for very small plate thicknesses. In this case, the collector efficiency factor becomes close to unity, almost irrespectively of the top loss coefficient, owing to the very small thermal resistance of polymer film. For very thick polymer plates, more than about 2 mm, there is a very significant reduction of collector efficiency factor, which becomes even more pronounced for higher values of top loss coefficient. Therefore, depending on the specific polymer collector absorber, the plate thickness should be optimized in order to offer protection against hydrostatic loads and provide adequate mechanical rigidity at a minimum thermal resistance.

For a parallel plate absorber design with vertically supporting ribs, an appreciably thinner absorber is likely to withstand the mechanical load, so a plate thickness smaller than typically about 1 to 1.5 mm appears to be a compromise, leading to collector efficiency factors higher than about 0.96.

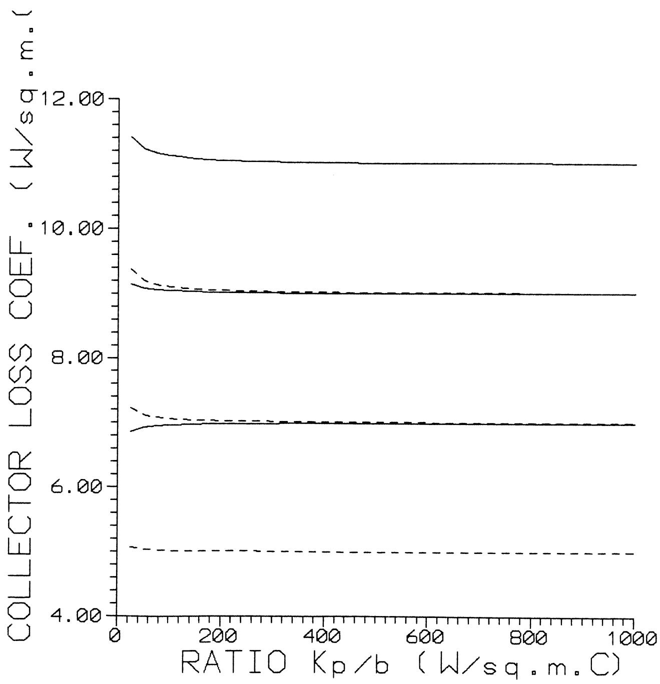

Fig. 4. The collector loss coefficient as a function of $H = k_p/b$. The two groups of solid and broken lines correspond to a base loss coefficient of 4 and 2 W/m^{2}C, respectively. Each group of the three solid and broken lines correspond to top loss coefficients of 7, 5 and 3 W/m^{2}C for the topmost and the following two lines underneath.

In Fig. 4, the collector loss coefficient is plotted as a function of $H = k_p/b$ for a combination of top and back loss coefficients as derived from expression (7) under the assumption of negligible collector peripheral heat losses. The two groups of solid and broken lines correspond to a base loss coefficient of 4 and 2 W/m^{2}C, respectively, while each group of three solid or broken lines correspond to a top loss coefficient of 7, 5 and 3 W/m^{2}C for the topmost and the following two lines underneath, respectively.

It can be seen that, for very small plate thicknesses, the parameter (H/U_b) becomes considerably high so that the quantity $[1 + (H/U_b)]^{-1}$ becomes negligible, and expression (7) leads to collector loss coefficients close to the algebraic sum of the top and base loss coefficients and both groups of the three lines tend to become parallel to the horizontal axis. For more than about 1.5 mm plate thickness, the reduction of parameter H becomes very significant, leading to increased numerical values of $[1 + (H/U_b)]^{-1}$. Then, the top loss coefficient is expressed as a linear combination of the numerical constants U_t and U_b. For even smaller values of H, the slope of the curves becomes either positive or negative, depending on the relative contribution of the two additive terms of Eq. (7) to U_L.

It is concluded that a considerable increase of plate thickness, practically more than about 1 to 1.5 mm, may possibly decrease the collector efficiency factor, but it would also possibly lead to either an increase or even decrease of collector loss coefficient, depending on the relative effects of U_t and U_b, owing to the inherent thermal resistance of the absorber polymer plate.

Derived typical long-term performance prediction results are shown in Fig. 5. In this plot,

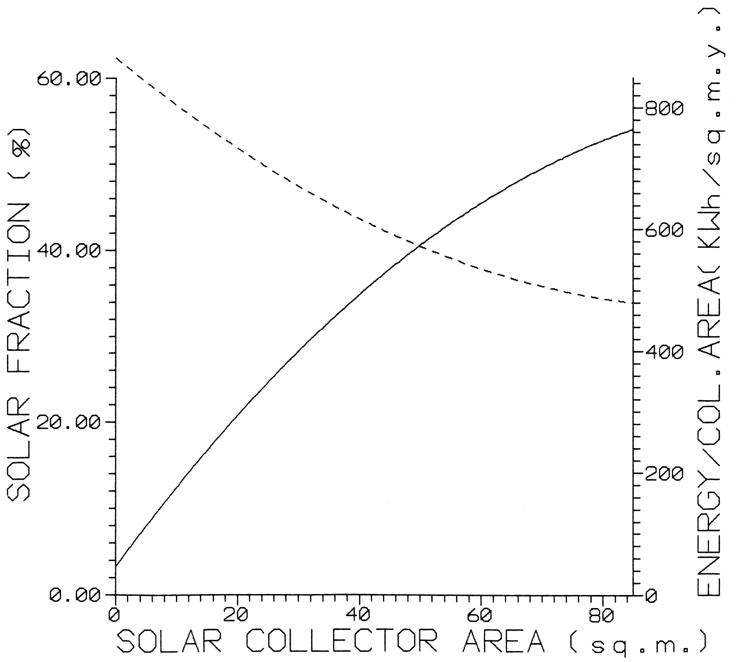

Fig. 5. The solar fraction as a function of the total solar collector area is shown by the solid line. The broken line represents the specific yearly energy collection defined as the energy collection per total collector area, as a function of collector area.

the solid line represents the yearly solar fraction as a function of collector field aperture area. It can be seen that a fraction as high as 40% of the yearly load can be covered by solar energy for the given size of solar system and load. The broken line in the same plot represents the yearly collected energy per unit area of the solar collectors. It is seen that the yearly average specific energy collection decreases with solar collector field area owing to operation of the collectors at lower inlet temperatures and, therefore, higher efficiency. The plotted results show that specific energy collection figures as high as 580 kWh/m^2 can theoretically be derived for the selected size of collector field, load and assumptions on plant component characteristics.

5. Comparable system costs and payback

Payback period, defined as the number of years needed for the accumulated present value of benefits corresponding to energy savings to become equal to the accumulated present value of the costs, is a very significant criterion for investment in large solar system technology through a commitment-based contract. Its evaluation is not only based on the accurate prediction of initial and annual costs but also on the accurate prediction of annual energy savings, which can be estimated by several long-term performance prediction models.

Based on previous preliminary cost estimates [5], it could be quite reasonable to assume unit area costs between 40 to 50\$/m^2 for the proposed collectors, which is appreciably lower than the current cost of conventional flat plate collectors. This is expected to reduce drastically the initial cost and the payback of plants, leading to investments more attractive to both parties.

To account for the effect of the idealized assumptions usually made in solar system modelling and in order to define a reasonable safety margin for the long-term average annual energy savings, it was decided to reduce the theoretically derived long-term energy savings by about 15%, so the payback calculations were performed for a yearly energy savings figure of about 500 kWh/m^2, which leads to a slightly more conservative evaluation of payback period.

The calculation of the payback period P is based on the balance between the present time cost of the system, which is the sum of initial plus yearly costs including operation, repair and maintenance, and the benefits from conventional energy savings referred to the present time,

$$C+c\left(\frac{1+e}{r-e}\right)\left[1-\left(\frac{1+e}{1+r}\right)^{\mathrm{P}}\right]=d\left(\frac{1+i}{r-i}\right)\left[1-\left(\frac{1+i}{1+r}\right)^{\mathrm{P}}\right] \tag{11}$$

with d being the yearly benefits and C, c the initial and yearly costs of the system, respectively. Assuming that r, i and e, the discount, inflation and escalation rates for the annual costs, respectively, and assuming for simplicity $e=i$, the solution of Eq. (11) in terms of P gives

$$P=\frac{\log[1-C(r-i)/(d-c)(1+i)]}{\log[(1+i)/(1+r)]}. \tag{12}$$

It is broadly agreed that a first-order approach for evaluation of the initial cost of a solar heating plant is represented with adequate accuracy by the following simple model expressing initial cost as a linear function of the collector field area

$$C = \varepsilon A_c + \lambda \tag{13}$$

with the constant ε representing the unit area cost of the employed collectors, and λ includes all fixed costs of a solar plant, irrespectively of the size of collector field. Apparently, the contribution of the first, area-dependent cost term for larger solar heating plants is appreciably stronger compared to the second, the contribution of which vanishes appreciably with the plant size. Owing to the considerable scatter of data for the second term and the domination of the area dependent term for the large plants, it was decided to ignore the fixed-cost component term for the first order evaluation of the plant initial cost.

The calculations were performed for a fixed inflation rate of $i = 5\%$, while the interest rate was allowed to vary in the range between $r = 9$ to 11%. It was also assumed that the displaced energy is Diesel oil at a cost of about 0.4 \$/litre, burned in a boiler with 80% efficiency and that the annual cost was fixed to be around 4% of the cost of the annual energy savings.

Comparative results are shown in Fig. 6 in which payback is plotted against interest rate for the unit area collector cost as a parameter. The solid and broken lines correspond to unit area cost of the proposed low-cost collectors in the range between 40–50\$/m^2 and to conventional flat plate collectors ranging between 120 to 150\$/m^2, respectively. It can be seen that the calculated payback for the systems using the proposed low-cost collectors was found to be between 2 to 2.5 years, irrespectively of interest rates, as compared to about 6.5 to almost 9 years for conventional flat plate collectors, depending on the unit area cost and interest rate.

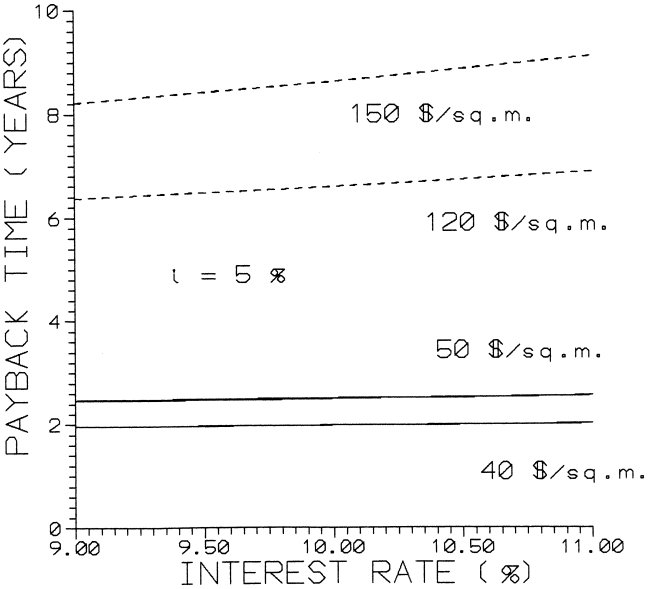

Fig. 6. Plot of the comparably calculated payback period as a function of interest rate for a fixed inflation rate of 5% for conventional flat plate collectors (broken lines) at a unit area cost of 120–150\$/m^2 and the proposed collectors (solid lines) at a corresponding cost of 40–50\$/m^2.

6. Conclusions

A simple and low-cost design of a low-temperature solar collector was proposed in the present work, aiming to make solar water heating technology investments more attractive for the purpose of a more successful competition with conventional energy. The design of the proposed collectors is based on extensive use of polymer materials and glass as a glazing material, and it is mainly offered for easy and low-cost erection of large solar collector fields at a fractional cost. However, the use of polymers in solar absorber design with a poor thermal conductivity, which is almost three orders of magnitude lower than metals, leads to a significant deviation from the basic assumptions made in the theory of flat plate solar collectors. Therefore, a simplified analysis was performed to investigate the limitations imposed by the thermophysical properties of polymers in the collector design and to account for their effects on long-term performance prediction investigations. Those investigations were conducted for a solar heating plant model, using clearly defined parameters for the proposed collectors and mechanical components, for a fixed heating load. The derived results were employed for comparative derivation of the payback period of a solar heating plant using the proposed and conventional collectors, respectively. The comparative results, showing a substantially lower payback for the proposed low-cost collectors, are clearly indicating that the future of large solar system technology strongly relies on commitment-based promotion of low-cost systems of innovative design.

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