P. RYBÁR, P. TAUŠ, R. RYBÁR, Ž. KUZEVIČOVÁ,
M. RYBÁROVÁ, Š. KUZEVIČ, M.CEHLÁR

ISSN 0543-5846
METABK 41 (2) 117 (2002)
UDC - UDK 620.97:621.47=20

UTILISATION OF FLAT SOLAR COLLECTORS IN URBAN BUILT-UP AREA

Received - Primljeno: 2000-04-26
Accepted - Prihvaćeno: 2002-01-15
Professional Paper - Strukovni rad

Active solar systems with flat liquid collectors for heating-up hot service water (HSW) or supplementary heating in the transitional period were in our country so far utilised especially in the extent of family houses' built-up areas or recreational facilities. This did not provide sufficient space for the construction of larger devices, which could in more important measure contribute to more favourable structure of energetical resources having the share in the production of heat for the population.

Key words: *solar system, the heat acquired by collectors, energy, saves of energy*

Korištenje ravnih solarnih kolektora u izgrađenim urbanim područjima. Aktivni solarni elementi s ravnim tekućinskim kolektorima za zagrijavanje vode za potrebe kućanstava ili za dodatno zagrijavanje stambenog prostora tijekom prijelaznog perioda, u našoj su se zemlji naročito koristili u dijelu područja izgrađenom za obiteljske kuće ili za rekreacione centre. To nije osiguravalo dovoljno prostora za izgradnju većih uređaja koji bi u nekoj značajnijoj mjeri doprinijeli povoljnijoj strukturi energetskih izvora koji imaju udjela u proizvodnji energije za potrebe pučanstva.

Ključne riječi: *solarni sustav, toplina dobivena kolektorima, energija, čuvanje (uštede) energije*

INTRODUCTION

The solar devices determined for the urban built-up area are advantageous because of the higher concentration of the population on a relative small area comparing with the area built-up by family houses, which enables to use a lower number of needed functional units, as are pumps, exchangers, expansion vessels, etc. The biggest advantage of the application in the urban built-up area is the existence of a supplementary source of heat, which is the heating plant's primary hot water circuit.

Principally there are two ways of application of solar collectors:

1. Large-area solar thermal systems with the long-term heat accumulation.
2. Solar systems placed on roofs of blocks of flats.

LARGE-AREA SOLAR THERMAL SYSTEMS WITH THE LONG-TERM HEAT ACCUMULATION

At optimum weather, technical, and constructional conditions in Košice it is possible to acquire from one square meter of the solar collector's absorber from 400 to 600 MJ of energy per month for the production of the HSW during the April - September period [1].

From data on the HSW consumption in individual quarters, where calculations and the project are concentrated, we will try to propose active solar system for the HSW pre-heating so that during the mentioned summer month it heats the water in large capacity tank to the temperature ca 70 °C. The capacity of the tank at the same time should cover the HSW consumption during the October - March period for the whole quarter, or for a certain number of forwarding stations in dependence on the area of the collector field that will be limited by the area of the surface suitable for these purposes.

The average monthly consumption of heat for one forwarding station in Košice represents ca 600 GJ. For covering this heat consumption in Košice would at optimum conditions suffice the total area of absorbers 1100 m^2, which at standard types of solar collectors with the absorption area ca 2 m^2 represents 550 pieces.

For the selection of the city part or the quarter of Košice, suitable for delivery of the HSW from the solar system were chosen the following criteria:

- sufficiently large free surface in the vicinity of the given city part;

P. Rybár, P. Tauš, R. Rybár, Ž. Kuzevičová, Š. Kuzevič, M. Cehlár, Faculty of BERG, M. Rybárová, Faculty of Electroengineering and Informatics, Technical University of Košice, Slovakia

- suitable orientation of the given surface at maximum ± 30° deviation from the south,
- the possibility of construction of a technical object on the given surface.

These requirements almost ideally meet the KVP quarter. The Čičky locality is situated in the KVP quarter, with the utilization of which is considered in the alternative No 1. It is approximately 5° slope inclined in the direction to the south and southwest, in the southeast direction its slope is approximately 10°. The main role at the selection of the place for the collector field, however, played the fact that this area belongs, according to the §17 of the Mining Act No 498/91 of the Coll. to the *Protected deposit area (PDA)*. In the PDA according to the §18 must not be built structures and facilities that are not connected with the exploitation of the exclusive deposit, without the agreement according this Act. This area is suitable first of all because the planned structure for our purpose does not require extraordinary measures for static stability of the subsoil and, moreover, it would take the land unsuitable for housing or industrial construction.

Alternative No 2 considered the collector field is situated within the *mining area* whiles for this area the Mining Act No 498/91 of the Coll. is of concern as well.

Boundary lines, giving the azimuth of the slope in the interval of ± 30° from the south direction limit individual surfaces. At larger deviation the utilization of solar collectors is already inefficient. On the basis of these criteria the following areas of the surfaces were determined:
- alternative No 1 (PDA): 305 760 m^2,
- alternative No 2: 190 800 m^2.

In case of these surfaces at optimum conditions it is possible to suppose that:
- in alternative No 1 at covering the whole considered surface by the solar collectors it would be possible to produce 166 TJ (46 GWh) of the energy for heating-up the HSW per year, which represents ca 270 forwarding stations with the power input of 600 GJ;
- in alternative No 2 at covering the whole considered surface by the solar collectors it would be possible to produce 104 TJ (ca 29 GWh) of the energy for heating-up the HSW per year, which represents ca 170 forwarding stations with the power input of 600 GJ.

SOLAR SYSTEMS SITUATED ON ROOFS OF BLOCKS OF FLATS

Their main parts are collector fields situated on roofs of blocks of flats. The solar tank is dimensioned so that 1 m^2 of the collector's absorption surface covers ca 50 l of the tank's volume [2]. The situating the collector field on the roof of the block of flat is given:
- by the area and shape of the roof;
- by the orientation of the object with regard to the cardinal points;
- by the roof's configuration, attic, and mouth of ventilation shafts;
- by the existence of the lift's machine room, its dimensions and situation;
- by the height of the building;
- by the existence of shadow obstacles as trees, other buildings, and situating in the space;
- by the structure's condition.

Suitable, for situating the solar collectors, are blocks of flats without the lift's machine room, being situated first of all in city parts Juh and Terasa, the blocks of flats with eccentrically situated lift's machine room (the KVP and Ťahanovce quarters), with the facade oriented mainly in the south direction. The existing system of the heat distribution incorporates the primary distribution:
- hot-water;
- steam piping (quarter Nad Jazerom).

In the city part Podhradová, local heating-up the HSW exists realized by two boiler houses. Forwarding the heat from the primary circuit is carried out by the system of forwarding stations (FS) in individual quarters. From the forwarding stations where the HSW and the water for the central heating (CH) is heated-up, the heat is delivered to individual housing objects by the four-pipe distribution system (HSW + back branch, CH + back branch). The main part of the forwarding stations is equipped by spatial horizontal pipe exchangers of obsolete construction with a low degree of heat-exchangeable area, after which must inevitably follow the section of spatial tanks.

The restructuring of facilities of heating-up the HSW and the water for the CH supposes replacing the FS by house exchanging stations, where heating-up the water for the CH and HSW is carried out directly in the object. House exchanging stations can be installed in already existing spaces of the technical floor of any block of flats. The small dimensions of the facility were achieved thanks to the use of counter-flow plate exchangers (mounted or brazed), with advantageous ratio of dimensions and area of the heat-exchangeable surface and high efficiency. In such a way in Košice, within the scope of modernization, several facilities were rebuilt (e. g. the FS 1138 in the Slobody street, quarter Terasa). For the heat supply to the house exchanging station suffices two-pipe primary distribution system. By verifying by pressure and dilatation tests it is possible to use the existing pair of piping of the same inside diameter.

The heat acquired by collectors is the most advantageous to use for preheating or heating-up the HSW. Graph 1 illustrates the share of the heat acquired by collectors

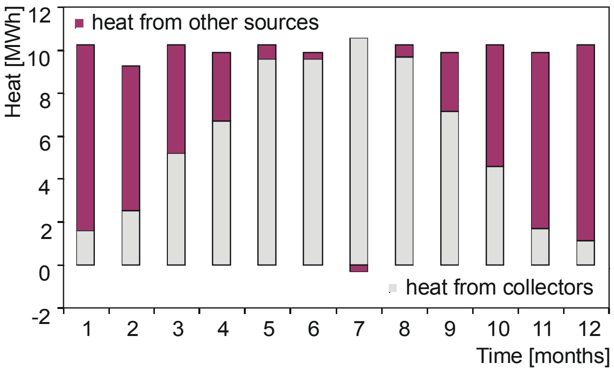

Figure 1. **Share of energy acquired by solar collectors on the total heat consumption for heating-up the HSW in individual months**

Slika 1. **Udio energije ostvarene solarnim kolektorima u ukupnoj potrošnji topline za zagrijavanje vode za potrebe kućanstva po pojedinim mjesecima**

placed on the roof of a block of flats with eight dwelling floors with the total number of four-rooms flats 32, and with considered 130 inhabitants. The assumed consumption of the HSW per one inhabitant according to the STN 06 0320 standard is 50 l. On the roof of 8-floor building with two lift's machine rooms with the utilizable area part of the roof that is non-shadowed during the whole year within the interval of angle of sun rays' impingement on the collector's absorber from - 90° to 90° from the azimuth of the collector oriented to the south) of 257 m^2 can be placed the collector field consisting of eight collector groups with the total absorption area of 83.52 m^2. The total built-up area by collectors is 80.64 m^2. In each group there are 6 flat vacuum collectors Heliostar 400 V, with the selective layer, of the producer Thermo/solar Žiar, with dimensions ca 1 x 2 m, with the absorption area 1.74 m^2/collector. The collector groups are connected:

a) Parallel (similar to the considered case),
b) Series parallel.

At the devices situated on the objects with sufficiently large utilizable area of the roof the series parallel connection of the collectors can be done. In this case, it is suitable to introduce into the scheme as the first the cheaper collectors with the higher heat-transfer coefficient on the front side of the absorber and thus with higher heat losses (by heating-up the medium on relatively low temperature their good efficiency is safeguarded), which preheats the heat carrying medium entering to the series connected collectors with low heat losses (in collectors with low heat losses the working substance can be preheated on higher temperature at safeguarding the same efficiency).

Some parts of the devices necessary for heating-up the HSW with the help of solar collectors are:

- the distribution Cu piping with favourable hydraulic characteristics and high service life or the piping of equivalent inside diameters made from the black steel;
- the pump of the solar circuit;
- the expansion vessel;
- closing and regulation fittings;
- measuring devices (flow meters, thermometers);
- insulation;
- the HSW tank with the inside diameter at the number of collectors 48 ca 4.3 m^2;
- the plate exchanger (primary system/CH);
- the plate exchanger (primary system/HSW);
- the plate exchanger (collector circuit/CH);
- the tank-exchanger circuit's pump.

The 8-floor buildings, located especially in quarters KVP and Ťahanovce, represent ideal case of the ratio of utilizable roof's surface, with the lifts' machine rooms, heigh objects, and the great number of inhabitants. In the KVP quarter there are approximately 18 buildings of the mentioned type oriented by the facade to the south, or with less than 30° deviation from the south direction, while the deviation from the west direction from the point of view of acquiring the solar energy is more advantageous. The effect of the deviation of the buildings' facades determining the orientation of collectors on the roof can be in calculations and considerations quantified by the correction coefficient with the value in the range of 0.90 - 1, which means decreasing the energetic profit of collectors on such buildings at maximum by 10 %.

In the mentioned buildings ca 2340 people live with the standardized HSW consumption 117 m^3 per year. For heating-up 117 m^3 from temperature t_0 = 10 °C on the discharge temperature t = 50 °C it is necessary ca 2.17 GWh of energy per year. The calculation considers with 10 % heat losses in distribution systems, exchangers, and fittings. By preheating the HSW with the help of solar collectors with the total number of 864 pieces in this case it is possible to save more than 1.2 GWh of the thermal energy per year produced in the heating plant with the combustion of the imported natural gas.

It is impossible not to mention, at the combustion of fossil fuels produced, quantity of gaseous emissions containing especially CO_x and SO_x, the elimination of which becomes one of priorities of energetics of developed Western countries, the evidence of which is also the legislative pressure on producers of emissions within the EU associated countries and preferring projects making the energetic infrastructure more healthy, through state subsidies or tax reliefs. As an example in the mentioned area the newly associated country of Austria can be shown.

Thanks to the favourable climatic conditions and relatively suitable structure of dwelling houses in Košice, and on the other hand due to the need of reconstruction of the heat distribution system (especially in older city parts, in which abundantly are represented objects with lower number of floors without lift's machine rooms, where by solar collectors it is possible to safeguard from 1/4 to 1/3 of the energy needed for the HSW heating-up), a topical question is restructuralisation of sources of energy in the direction to renewable sources, the utilization of which is in accordance with principles of the protection of the life environment and at the same time they represent the alternative, to the advantage of which the energies' price development as well [3] will probably be oriented.

The solar systems can be evaluated in the same way as other technical devices according to their economical efficiency. In comparing with other sources of energy in the calculation it is necessary to take into consideration also the character of energy, and in this case, it is the environmentally pure source that does not harm the life environment, and thus saves cots for the regeneration of the life environment. Also this is one of the factors that so far were not taken into calculations. Besides this it is necessary to take into account also the following factors:

a) assumed increasing the energy prices;
b) assumed development of prices for components of the solar systems;
c) assumed development of interest and discount rates in the monetary system;
d) possible subsidies representing the interest of state to follow certain development conceptions.

Moreover, it is necessary to take into consideration that a simple justifying energetic saves following from the energetic balance does not mean the actual economical evaluation. The energetic advantage need not mean neither the advantage from the point of view of the whole economy. It is necessary to respect also the data on prices of other sources of energy, and on investment costs and the service life of the solar systems and their components. Only then it is possible to carry out the calculation at which unambiguously it can be defined the suitability or unsuitability, i. e. from the point of view of investment costs, operational costs, pay back time, environmental impact, and mainly the restructuralization and diversification of energy resources.

General orientation of advantages of active solar systems enables the so-called *degree of covering the energy consumption*

$$S = \frac{Q_{\mathrm{cons}}}{Q_{\mathrm{A}}}$$

where

Q_A specific energy caught by collectors for a certain period [kWh/m^2],
S area of collectors [m^2],
Q_{cons} consumption of energy for the same period as the Q_A [kWh].

The annual degree of covering the energy consumption should always be $f < 1$. If $f > 1$ the area of collectors is needlessly large and from the investment point of view it is expansive and non-economical [1].

REFERENCES

1. J. Cihelka: Solar thermal technique. Publishing house T. Malina, Prague, 1994
2. M. Halahyja, J. Valášek: Utilization of solar Energy, ALFA, Bratislava, 1983 (Original in Slovak)
3. P. Rybár, P. Tauš, R. Rybár: Alternative sources of energy I. (University textbook). ELFA Košice, 2001 (Original in Slovak)