SOLAR COLLECTOR

„... Nature friendly energy, clean and sustainable quality of life...
The vision of the new future...? Yes...!
With the help of the lively sunshine our solar collectors bring the new and clean, easily payable energy nearby to us, the real future.”

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The solar collector designed and released by PÉTER IMPEX Ltd. is protected by the number 000838586-0001/ 000838586-0002/ 000838586-0003 community design patent statement, and number U 06 00268 utility model patent, furthermore the P 07 00564 number patent was applied, therefore is a product protected by law.
The possible utilization of the solar energy

The seriously rising need of energy for the humanity is mostly provided by fossil energy carriers (coal, oil, gas, etc.). The possibility of using these resources is not inexhaustible, and it is also not a renewable process, since the decreasing supplies can be replaced with expensive investments, and we receive a decreasing value even calculating with the discovered reserves. The harming materials (carbon dioxide and sulphur dioxide) entering the atmosphere are destroying the quality of the air, are influencing the radiation of the Earth, and the increase of these substances cause the extreme warming of the Earth, this way endangering its energy-balance.

Consequently the more and more polluted air around us – thanks to the present energy manage – has a higher effect on nature as well. The natural disasters are more and more present (storms, floods, etc.) and this situation should make the society analyze these signs, and find professional solutions, giving a louder and more radical notice to the decision makers.

According to experts the solution could be the environment friendly way of living, and its main components would be the energy saving and the use of renewable energy resources.

The renewable energy resources provide that new energy which always or cyclically is at our disposal, it is nearly inexhaustible measured by human extent, when used the natural energy balance of the Earth is not modified, and it does not cause irreversible environment load. The common characters of the renewable energies are that they are produced and supplied by the Sun. The effects of the sunrays produce a diversity of natural actions, which can be used for direct or indirect energy production.

Energy resources to be used in indirect actions:
- Wind energy
- Water energy
- Biomass
- Ground heat

Energy resources to be used in direct actions:
- Passive utilization
- Active utilization  
  - Solar cells
  - Solar collectors

The characteristics of the sunlight

The Earth’s most important energy source is the Sun. Thanks to the sunrays the surface of the Earth and the air right above the surface warms up, therefore the Earth’s average temperature reaches +17°C even though it is in the outer space which is -270°C. This way life can develop and be maintained on the Earth. Inside the Sun there is thermonuclear fusion, thanks to which heat is produced, while Hydrogen is transformed to Helium. Due to the nuclear fusion the temperature of the Sun’s surface approaches the 6000°K. As a consequence of this high temperature the Sun emits short waves of electromagnetic rays of light. From the sun-radiance power of \(4\times10^{23}\) kW the surface of the Earth reaches \(173\times10^{12}\) kW. From the sunrays approaching the edge of the atmosphere only some proportion reaches the surface of the Earth. According to the calculations out of the total sunrays 23% is absorbed by the gases in the air, transforming it to heat, 26% is reflected or radiated back to the space in the form of stray rays. This way only 51% reaches the surface of the Earth, 33% as direct shortwave radiation and 18% as diffuse radiation. Out of this proportion the Earth’s surface reflects 10%, 5% is absorbed in the atmosphere, and 5% exits to the space. The sunray household of the Earth – which exceeds the energy needs of the humanity more than thousand times – is constantly balanced in average, but the value is variable with the weather changes. The main cause of this phenomenon is the Earth’s geometrical relationship to the Sun.

The proportion of the sunrays at the edge of the atmosphere can be divided in the following manner:
- Ultraviolet radiation 9%
- Visible light 49%
- Infrared (heat-) radiation 42%

According to the data described above the atmosphere weakens the sunrays arriving to the Earth surface, which is highly effected by the clouds and fog present, due to the weather changes. These clouds reflect or absorb most of the sunrays. Between the axis of the Earth and its circle around the Sun there is 23.5° difference, therefore the visible orbit of the Sun on the sky is different every day. This orbit is lower wintertime, and higher summertime, which naturally influences the usable energy. Since Hungary can be found in the north tempered zone, on the north latitude between 45.8° and 48.6°, the number of sunny hours is approximately 2100 hours/year, the heat quantity of the arriving sunrays is \(~1300\) kWh/m\(^2\) year, the highest peak summertime, at noon, in case of clean sky can reach, or exceed the 1000 W/m\(^2\)

In Hungary the highest value of this heat quantity – approximately 1450 kWh/m\(^2\) yearly – arrives to the southern situated surfaces, having 40-42° lean. This value is utilized by the solar collector, thanks to its optimal lean, situation, and also depending on the type of the equipment utilizing the solar energy, or the works condition.

The question is also arisen, is it practical to rotate the solar collector direction to the Sun. Since most of the sunrays are arriving to the surface without any definite direction and are stray rays, following the movement of the Sun would be more complicated and more expensive, than being worth getting a higher performance.
General built-up of the solar collector systems

In Hungary – thanks to its relatively good climate conditions – mostly the liquid medium is used in solar collectors for utilizing the solar energy.

These solar collectors producing heat are mostly consisting of the following elements:
- Solar collectors, which absorb and transmit the transformed heat, coming from the solar energy, to the liquid medium.
- Containers, which store the heat produced by the solar collector in the form of warm water.
- Operator, regulator, and safety, controlling appliances. Here belongs the circulating pump, the automation, the expansion reservoir, the safety valve, the pressure- and thermometers, the control and switch valves, and other appliances.
- Piping, which connects the collectors with the reservoir and the user.

The solar collector systems depending on the liquid used in the system can be one or two circled.
- In the case of one circled collector the heated liquid which circles in the collector is the water for direct use itself. The advantage of this system is the simplicity, the disadvantage is that it must be used when there is no freezing outside. It is also a problem that lime-scale is produced while used or there is a hazard of the water boiling.
- In the case of two-circled system the collector circle (primary) is a separate closed circle, which is filled up with antifreeze liquid. The antifreeze warmed up in the collector warms up the water in the reservoir with the help of a proper heat panel. Technically it is possible to omit the antifreeze liquid, and use water, which enables better heat exchange, but a smaller reservoir and a small automatics is needed in this case.
- The double circle systems can be used safely all year round, their advantage is the higher yearly yield, the safe use, by eliminating the lime-scale, though their disadvantage is the higher costs due to the heat panel, and also the more complicated operation.

Based on the liquid work medium, the solar collector systems can be grouped into gravitational or pump operated circulation systems.
- In the case of gravitational circulation system (based on specific gravity variance) the reservoir is placed above the collectors, where the circulation of the heat transmitting work medium, thanks to the solar energy, is a result of the specific gravity variance of the heated liquid. The advantage of these systems is their simplicity, the omitting of the circulation pump and the automation, their disadvantage is the fix position of the reservoir. In the case of gravitational systems, the pressure difference of the circulation system is relatively small, therefore only small flaw resistance collectors, pipes and reservoirs can be used.
- In the case of pump operated circulation systems the heat transmitting liquid is flowed by a pump. The advantage of the pump-operated systems is, that the reservoir can be placed anywhere, an extensive system can be built, it is not necessary to use small flaw resistance units, and with the switch-on, switch-off the pump, or by changing the RPM (revolution per minute), a well controlled operation can be realized. Their disadvantage is the higher investment, and operation cost.

The operation, and built-up of the solar collectors

The sunrays are reflected, absorbed, or let passed through the different objects, based on their material, built-up. Heat is produced, if the object absorbs the sunrays. Therefore the aim of the solar collectors is to absorb the highest number of sunrays.

That system, which absorbs, and transfers the solar energy, and passes to the liquid work medium, is called solar collector (collector of solar energy).

The most important element of the solar collector is the heat absorber. Its task is to absorb the solar energy and transform to heat, as well as to transfer the resulted heat to the work medium circulated in the collector.

Each black colored, and unpolished surfaced material absorbs the sunrays, depending of its efficacy, until its temperature does not get higher compared to its environment. On that point they become also radiant, which is loss of energy. Here comes the importance of the good design, and good technological solutions.
The characteristics of the Solar Collector, produced and distributed by Péter ImpeX Ltd. and Partners

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There is no mediatory element between the absorber heat transferring surface and the heating medium, therefore there is no galvanic rusting, which would work as an insulation, there is no bad pressing, bad assembling, which would result in lowering the efficacy of the system.

The main element of the collector is the special alloyed aluminum plate profile, which is pressed in warm conditions just for this reason, and in which a small depth of liquid channel is made through plating. The panels are fixed parallel at a distance from each other, the endings are fixed into the distributing and collecting pipe area, this way ensuring an ideal 1,7 l of cubic capacity, and the two inputs and two outputs.

- Our product’s other important characteristic is a homogenous and exclusive alloyed aluminum material, made and used especially for this purpose, which possesses a very good heat conducting capacity (235 W/m°C), is long lasting, resistant to corrosion, its mass is small (less than 2,8 kg/dm³), it is easy to work with, easy to assemble, and it is relatively cheap.

- The third, and other important characteristic of our product is the surface treatment of the solar collector, different from other products. The surface treatment of the alloyed aluminum plate, used by us is unpolished black elox, which can absorb the Sun’s rays at a relatively high amount (approximately 85%), and its specific heat emission capacity compared to its temperature is relatively low (15%).

The elox coating is taken up through electro-chemistry way, making its surface more endurable, since on the surface a 10-18 micron thick solid metallic oxid-layer is shaped up. This solid layer is insulating electrically, therefore it rules out the possibility of galvanic rust, on the other hand is aesthetic, its heat insulation is insignificant, its efficiency is very high.

- The collector house is a very important element of the collector, which usually is made of aluminum panels. Its task is the covering and heat insulation, keeping the absorber in a closed unit, closing down the collector, and preventing the humidity entering the collector. Making the collector house was an important aspect of our company, therefore we used a specially alloyed aluminum panel profile. Its advantage is thanks to its size that the collector is aesthetic and its mass is lowered, its thickness is only 6,1 cm, its outer size is 2,0 x 1,0 m, its mass 38,6 kg. The bottom of the collector house is an alloyed aluminum panel rolled in a cold manner.

- The other important element of the collector is the closing glass panel. Its task is to let the sun pass through and also hold it back through its good quality transparency panel (in our case: 1,94 x 0,94 m), and with its heat insulation capacity reduce the convective heat waste of the absorber panel.

Usually high purity, content low in iron, tempered anti-reflexion solar glass is used, and this is applied to our product, as well. The tempering and thickness of the glass (4 mm) ensures that it does not get broken during the transportation and installation, and resists the snow layer and the heavy hail.

- In order to rise the efficiency of the solar collectors, normally heat insulation is used, which is generally mineral cotton. Our company is using polystyrene together with heat reflecting foil, or a combined mineral cotton – polystyrene heat insulation.

- In the case of the collector an important element was to be dismountable, its parts to be exchangeable, and also the inner capacity’s vapor can be abandoned.

The solar collectors’ areas of usage, elements of selection

In the market the following solar collectors can be found:
- without a cover, flat collectors without specific coating,
- flat collector, without specific coating, but with a cover,
- specifically coated flat collector with a cover (most frequently used ones),
- specifically coated, vacuum flat collector,
- vacuum pipe collector.

The solar collectors are mostly used for the heating of indoor or outdoor pools, heating water for daily usage, or for supplementary heating of buildings. These usages are meaning different operations, therefore need different requirements.

- Heating outdoor pools

Summertime, the average temperature of the solar collectors used for heating outdoor pools is not more than the temperature of the air. The air temperature is 25-32°C, the pool’s water temperature is 24-28°C, which can be heated with a collector of 35-40°C temperature. The radiated power is ~800 W/m². In this case the independent variable in the solar collector efficiency formula is \( X = 0.0-0.2 \).

The worst efficiency in this situation, due to the strong reflexion, is in the case of vacuum pipe collectors. Therefore in the case of outdoor pools simple, cheap collectors without coating can be efficiently used, even these ones are manufactures especially for these purposes.
The solar collector systems consist of the following main parts:

- Solar collectors, which absorb and transform the solar energy to heat.
- Reservoirs, which store the heat, produced by solar collectors, in the form of warm water, for the cases when there is no sunshine.
- Operating, controlling, safety machines, accessories. Here belong the circulation pump, the automatics, expansion tank, safety valve, trap valve, manometer, thermometer and other accessories.

General requirements:

The main element of the hot-water producing solar collector systems is the solar collector itself. But in order to have a proper working and highly efficient system, we need to choose well the other accessories as well.

The realization of the solar collector system is a building mechanical engineering task, the installation processes are similar to the heating and water-pipe system installations. The used constructional and installation materials are also similar. But you can meet some special considerations, which you should highly take into consideration.

These are the following ones:

- The solar collector systems do not have a fixed, permanent performance. The energy supplied by the collector can vary from time to time, depending on the sunshine and the temperature. Therefore when designing and calculating the system, you have to calculate with the daily or a given period’s general utilizable heat amount.
- The neutral gear temperature of the good quality collectors can be very high, can reach the 180°C. Neutral gear can always happen, one cannot fend it off (e.g. power cut) therefore when restarting the system – for a short period – this high temperature, which can be above 100°C, appears in the system, and all the accessories must endure this heat. Therefore plastic pipes, or pipes with plastic elements cannot be applied.
- One must take into consideration the thermal expansion possibilities, above a given performance the collector must be cooled in summertime.
- Due to the high agent temperature, the operation pressure is also high, therefore to avoid the boiling of the heat carrier agent, the operation pressure must be defined very carefully, which also effects the temperature of the boiling point. Therefore the operation pressure should be fixed under 3-4 bar, since in this case boiling point of the mixture of the antifreeze and water does not get higher than 150°C.
- In building construction generally 1-1.5 bar operation pressure is used with a safety valve enduring 2.5 bar pressure. Therefore it must be verified that the highest allowable pressure of the applied accessories must be higher than the opening pressure of the safety valve.
- Solar collectors used all year round must be filled up with antifreeze liquid. This process requires attention and caution, since these liquids are poisonous, propylene-glycol base, or monopropylene-glycol base liquids, and also it must be verified that these liquids do not get into the drinking water system.

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The most frequent usage of solar collectors is heating water for daily usage. In the case of heating water for everyday usage the temperature of the collectors is 30-40°C degrees more than the air temperature, in this case the independent variable of the efficiency is X>0.04. In this operation the efficiency of the flat and vacuum collectors is nearly the same, approximately 60% therefore the cheaper and easily assembled flat collectors are used.

Indoor pools heating

Heating indoor pools all year round is a much better operation for collectors than heating water for every day usage. The reason for this is that they have to heat a relatively cold pool all year round. In this operational case a 5% higher performance can be achieved with the vacuum collector than with the flat ones, even though the flat ones are more resistant and are cheaper investments.

Supplementary heating of buildings

The difference of temperature between the collector and the air in case of heating buildings is 40-60°C, but the value of solar radiation is generally 400-500 W/m². This way the efficiency parameter is around X = 0.1. In this operational case the best efficiency can be reached with the vacuum pipe and the flat collector, since the good quality heat insulation has got a high advantage.

Heating water for daily usage all year round

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In Hungary based on its meteorological conditions, only solar collectors cannot produce the all year round thermal need for the various fields of use. Therefore the solar collector systems are utilized parallel with the traditional energy carrier heat producers. When designing the dimensions of the solar collector the most important aim is to realize which size is the optimal system, and in what proportion it can meet the heat need for a given task. The quotient of the heat need covered by the collectors, and the completely needed heat need is called the solar partial proportion.

The other important aspect of the solar collectors is the system efficiency, which is the quotient of the utilized solar radiation by the collector, and the solar radiation arriving to the surface of the collectors.

Drawing the two characteristics into a chart, we can realize that their direction is just opposite. The systems with low solar partial proportion work with high efficiency, though high solar partial proportion can only be reached by low system efficiency. The optimal solar partial proportion depends on several factors. In the case of small systems producing warm water for use, or family houses the 50-70% efficiency most probably can be reached. In the case of bigger systems the lower, 20-50% value should be aimed at, the saving is still significant. In both cases the all year round efficiency of the solar collector, the trustable operation, and the refund of the investment expenses are important.

Solar partial proportion = Heat amount of collectors / Complete heat need
System efficiency = Utilized solar radiation / The utilizable heat amount by solar collector systems

More accurate dimension setting of a solar collector can be done through a computer simulation software, which is able to make all the complex calculations, of collectors dimensions depending on several factors, after given all the parameters found in natural systems.

Without a computational method it is difficult to design the dimensions of solar collector systems. Simplifying formula, maps or monograms exist, with which approaching pre-measurements can be made.

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Designing the dimensions of warm water preparation systems

First of all the measured location’s daily warm water need must be determined. This can be done by calculations, personal water usage estimation, or based on the location’s owner, user information.

Daily water usage: \( V = nV_1 \) [l/day]

Abbreviation:
- \( n \): the number of people using the system,
- \( V_1 \): the warm water usage per person [l/day]
- In the case of family houses from 45°C water:
  - \( V_1 = 60-120 \) high demand,
  - \( V_1 = 40-60 \) average demand,
  - \( V_1 = 30-40 \) low demand
- In case of hotels, pensions from 45°C water:
  - \( V_1 = 50-100 \)
- In case of restaurants, kitchens from 60°C water:
  - \( V_1 = 5 \) liter / portion

Other constructional data can be obtained from books of building construction. If possible one should ask real data from the end-user.

The heat quantity required for the daily warm water production:
\[
Q_{\text{Warm Water}} = 1,1 \cdot c \rho V (t_m - t_h) \quad \text{[Wh/day]}
\]

Signs and abbreviation:
- \( c = 1,16 \) Wh/kg·K the specific heat of water,
- \( \rho = 1 \) kg/l water density,
- \( t_h = 10-15°C \) the temperature of cold water,
- \( t_m = 45-60°C \) the temperature of warm water at the time of using.

In the formula the 1,1 multiplier takes the storing and application loss into account. If the warm water is floated, the heat need must be increased with 10-20% due to the circulation heat loss.

The general value of utilizable heat amount during summertime: \( Q_{\text{summer}} = \sim 2.8 \) kWh/m²/day

The general value of utilizable heat amount during wintertime: \( Q_{\text{winter}} = \sim 1.1 \) kWh/m²/day

The warm water reservoir should be designed that way that its capacity should be nearly the same as the amount of daily warm water use calculated for 45°C. The value set up for the utilizable solar radiation must be modified depending on the collector’s position. In Hungary, used all year round the optimal collector position is with 40-43° lean and it is facing south. Deviation from this optimal position results the “k” value, which is the decrease of performance value.

The number of collectors needed:
\[
k = 1,2 \cdot f_t \cdot f_{dm} \cdot \frac{Q}{A_{coll}} \cdot Q_{\text{summer}}
\]

Where:
- \( f_t \) – factor of adjustment depending on the position
- \( f_{dm} \) – factor of adjustment depending on the angle
- \( A_{coll} \) – the usable surface of the collector (in our case: \( A_{coll} = 1.82 \) m²)

Systems making warm water for use should be dimensioned that way that in the case of a general summer day the complete amount of warm water needed can be produced by them.

Designing the dimensions of systems heating buildings and pools

The solar collectors used for helping in central heating systems should be used in the case of the following types of buildings
- The building’s heat insulation is higher than normal, therefore the heat loss is minimal.
- The building was built based on the rules of the passive solar energy utilization, or in other words its adjustment, its glazed surfaces, and the used materials are constructed that way that the building utilizes the solar energy on a maximum percentage.
- The building possesses low temperature, central water heating, such as floor or wall heating, or the low temperature radiator heating.

Solar collectors can be used mostly for helping heating in the transition periods, such as in autumn and in springtime. Based on experience models with 1m² of solar collector surface 4-5m² building heating can be helped out efficiently. In the case of a building settled up with this proportion the solar collectors can provide the heat nearly 100% from mid-March till mid-October.

Building heating solar collector systems can be used efficiently if the energy produced by the collectors can be used all year round, so summertime as well. Therefore these kinds of systems are producing warm water for use as well, but the best situation is when summertime these collectors are heating outdoor pools, which need heat during summertime as well.
Solar collector system producing warm water for use

Solar collectors are heating a standing warm water reservoir with two heat exchangers, through the built-in pipe. The reservoir’s traditional heating is done with a standing boiler, through the upper pipe. Besides the boiler the reservoir can be heated with an electrical heating patron built-in on a medium-height settlement.

Solar collector system heating pools

Solar collectors are heating pools through the heat exchanger built-in to the water-circling pipe. The controller starts the water circling pump as well as the collector circle pump when the collector starts heating the pool. The pool can be heated traditionally with a boiler, through the heat exchanger built-in to the water-circling pipe.

Solar collector system making warm water for use, and additionally heating buildings and pools

Solar collectors produce warm water in a warm water reservoir with two heat exchangers, trough the lower pipe, and they help-out the building heating system through a puffer-reservoir heated with an external heat exchanger. While they heat pools with a heat exchanger built into the water circling system. The additional heating is realized that way that if the temperature is higher in the upper zone of the puffer-reservoir than the returning water’s temperature, an electric cross valve drives the returning heating water to the lower zone of the puffer-reservoir, while to the boiler the warmer water, heated by the collector arrives from the upper zone of the puffer-reservoir. The collectors, due to the advantage switching, first heat the warm water reservoir, then the puffer reservoir and finally the pool. The switches are realized with two electric cross valves. Producing warm water is done from the puffer-reservoir through the upper heat exchanger of the reservoir, or if there is not enough heat, then with the boiler. The pool can also be heated with a boiler, parallel with the collector.