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ESTIMATION OF FLAT PLATE SOLAR COLLECTOR PRODUCTIVITY

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Abstract- The paper is about the experimental study of the flat solar collector productivity. Here by using the present method average monthly and annual productivity calculation of the solar collector was realized. The solar plant has some advantages to achieve necessary technical and economical profits while applying in any field. Firstly the plant possesses suntracking system on both surfaces. The azimuthal and zenithal sun tracking systems increase the efficiency of the solar collector. Therefore there's no solar energy loss in this plant. From energy point of view the plant can profitably work at both solar radiations (direct and diffuse solar radiation). Besides the technical and energy prevalences the equipment belongs to economical priority. The utilization and production are profitable for manufacturer and consumer. Because the equipment can pay back the expenditures used to the production and building-up processes. The prepared collector's cost is economical beneficial which was constructed, built and tested on the base of the local materials. Natural solar energy potential of Absheron peninsula and technical facilities of the flat solar energy plant let us to use ecological clean, economical fruitful, energy effective energy source in life and industry sectors. Taking into considration all important showings of the energy plant, the very solar collector was validated due to the technical opportunities, ecological safety, and economical serviceability.

Keywords: Solar Energy, Flat Plate Collector, Productivity, Solar Radiation.

I. INTRODUCTION

At present the flat solar collectors having different types are being widely applied in solar energy field. For exploitation of solar collectors specialists initially define some necessary parameters and factors. The natural solar energy potential is measured, processed and mapped for developing the current energy equipment. The regular construction of the using plant has great importance to solve energy losses and deficiencies in advance before the production process. The reliable construction gives guarantee to the plant to work perfectly and to check out the working regime in time. Also climatic condition where the equipment can be applied should be taken into consideration while constructing the flat solar collector. As for the thermal-energy properties of the plant, this parameter may realize the energy effectiveness of the presented plant. The plant is to be utilized in any field of the life and industry depending on the purpose of the users. Sometimes in energy consuming processes the thermal-energy manufacturability of the plant increases the worthiness, feasibility in implementation.

Of course for constructing and building up the solar energy plants take much more expenses. The provisional financial implications demand previous economical sufficiency. Each investor who is interested in the manufacturing of the solar energy plant needs to define the economical benefit of the product. If the processing is not satisfactory in this case the solar energy plant making doesn't attract the attention of the investors, indeed. The solar energy collectors projecting having abnormal thermal-energy, climatic and technical parameters fails economically and the labor spent to such construction leads unsuccessful completion in energy sector for manufacturer.

All endeavors of the specialists and the persons who were busy with this are in vain. It stands energy specialists ought to take into account these parameters and demandable factors beforehand. That's why study of the flat solar collectors requires the mentioned parameters investigation step by step. The climatic, thermal-energy, economical parameter of the flat solar collectors is important for manufacturer to determine technical validity and advantages of them. Therefore, there parameters are detailed in time while constructing the energy plant. The presented flat solar collector is mainly used for hot water supply and heating systems in suitable field of the life and industry. Depending on order several temperatures are obtained in such solar collectors. Thus in the flat solar collector water can be heated till 90-100^0 C depending on productivity till the boiling temperature. This temperature is enough for us to realize various technological processes (crude oil treatment, cleaning of water and oil field equipments, desalination of the sea water and so on) in oil field condition. For these technological procedures process water is mainly used to be heated.

Azerbaijan is the oil country that's why in this sector there is a great deal of energy consuming processes. This results the exploitation of crude oil for these. Because of power-intensive demand new economical beneficial energy source has to apply in oil sector. All over the world the study of solar energy utilization in oil fields was firstly carried out in Azerbaijan. So generally I dare say that Azerbaijan takes the first place because of the investigations on solar and wind energy application in oil field among world countries [1-6]. This is why as the projection of this technological process the new flat solar collector had been firstly built at "Petroleum and Reservoir Engineering department" of Azerbaijan State Oil Academy [7]. The general view of the collector is in below.

Figure 1. The flat plate solar collector

The experimental plant was built up in the oil field for realizing some technological processes. The 90% of oil-gas extracting departments are located in Absheron peninsula, Azerbaijan. That is why all experiments were fitted to the natural condition of the peninsula. So the plant was tested in the open air in Absheron peninsula within the oil field [7]. Up today the some Azerbaijani specialists tried to design flat solar collectors.

Depending on the above mentioned parameters deficiency those flat solar collectors failed in working regime. In the 60-70th years of the last century some solar collectors were prepared in Baku, Azerbaijan. They had absorbers made from black river sand and their efficiency was too below, therefore they weren't extensively utilized [8]. Because material selection of absorber wasn't properly directed while constructed. The climatic, thermal-energy, economical, technical parameters have chain relation one another. If one of these misses in that case none of effectiveness at the flat solar collector is spoken. That's why the first designed flat solar collector based on river sand absorber couldn't prove itself by thermal-energy, technical point of view. While constructing the flat solar collector the predecessor's deficiencies were taken into account.

So, more effective solar collectors had to be created for exploitation in the local energy sector [9]. Currently collectors are being sold in Azerbaijan which is made in China and Turkey. Their average cost is 800 $ for each 1 m^2 at the local market. The thermal-energy, technical facilities and economical profitability is not satisfactory for users and also vendor. Because the custom taxes and transportation expenditures makes the sellers to vend expensively such flat solar collector. The vendees' order is not suitable to the offer of the sellers who purchases Chinese and Turkish solar collector at the local market.

Because their climatic parameters, technical indexes, thermal-energy parameters can't validate the economical cost of these solar collectors. But while experiments and development new type flat solar collectors I revealed that the local produced flat solar collectors are more effective from technical and economical point of view. In order to produce the flat solar energy collectors there enough labor force, technical effective materials, work condition and demandable local market. Due to the technical indexes much more effective collector individual production takes averagely 100-150 $ for 1 m^2 in local condition. At the high-volume production this showing will be enough below. This sum fits to the average monthly salary of the population. For new flat solar collector, one of the major technical parameters of the collector is productivity calculation [10, 11].

II. MATERIAL AND METHOD

The research area is located in Absheron peninsula. The experiments have been carried out in the condition of oil-gas extracting department. The flat solar energy collector was utilized in several technological processes having different energy consuming procedures. It stands efficiency and productivity of the solar collector is more interesting for realizing the work. That's why in selection of absorber material the detail showings were taken into consideration. Initially absolute black body of flat solar collector was designed from copper because of its excellent heating transfer capability. The main element of the flat solar collector is absorber. It is made from the metal (copper or aluminum) having highest heat conductivity capacity. The selective cover on the absorber must maximally absorb and minimally reflect sun rays in infrared spectrum. In order to estimate the effectiveness of absorbing surface these indexes are used:

- Ray absorbing coefficient (absorption). Usually this index changes between 0.7-0.98 interval. This coefficient is accepted as relation of the absorbed energy to the falling total energy;
- Radiation coefficient (emission). These changes between 0.95-0.02 interval on different type surfaces. This coefficient is accepted as relation of the radiated energy to the absorbed energy;
- Selective coefficient. In order to compare technical characteristics of several absorbing surfaces. How much this coefficient is higher absorbing surface will have much more positive characteristics.
- The modern flat solar collectors' high efficiency is connected with their selective surface showings;
- Heat conducting coefficient. Sun rays absorption depends on absorber's material. That is accepted as transformation of solar energy (receiving by the selective cover) to the effective energy. So this energy is transferred to the heat-carrying fluid and realizes heating process;
- High interval between outlet and inlet temperatures of the heat-carrying fluid due to the heating on the absorber depending on solar radiation;
- Durability and long-standing ability of the selective cover on the absorber.

The flat solar collectors are effective from technical and economical point of view. Due to the above mentioned properties the calculations were realized. Initially productivity at working hours a day of the solar collector having plane surface should be determined [9].

$$G = \frac{Q_{effec}}{c \cdot \gamma (t_{hotwater} - t_{coldwater})} \quad (1)$$

where,

Q_{effec}: Effective solar energy amount used for heating water, kcal/m^{2}hour;

c: Water heat capacity = 1, kcal/kg ^{0}C;

γ: Water specific weight = 1, kg/liter;

$t_{hotwater}$: Hot water calculated temperature, ^{0}C;

$t_{coldwater}$: Cold water temperature from the source, ^{0}C.

The Q_{effec} depends mainly on direct or diffuse solar radiation, environmental and cold water temperature from the source, absorber's material, blackness degree of the selective surface, quality of the heat isolation, the collector location. Besides in clean air determination of flat solar collector productivity is easy, so in half cloudy weather that's difficult. Firstly, in order to reveal average monthly productivity of the flat solar collector some parameters have to be known. Thus average monthly amount of solar radiation perpendicularly falling on the collector surface or average monthly amount of sunshine hours ought to be defined in advance.

The effective heat amount being used for water heating during a month can be determined.

$$Q_{effec}^{m} = Q_{\perp}^{m} \cdot \eta_m \ \text{kcal/m}^2\text{month} \quad (2)$$

where $\eta_m = \frac{Q_{effec}}{Q_{\perp}}$ is calculation average absolute efficiency of average monthly solar radiation during a month.

So, average monthly productivity of the flat solar collector will be:

$$G_m \frac{Q_{effec}^{m}}{(t_{hotwater} - t_{coldwater}) \cdot c \cdot \gamma} \text{liter/m}^2\text{month} \quad (3)$$

The heat amount demanded for water heating can be defined:

$$Q_{effec} = Q_w - Q_{heat} - Q_{loss} \quad (4)$$

where,

Q_w: Heat amount of collector absorber's working surface;

Q_{heat}: Heat amount used for heating the plant from cold state till working temperature;

Q_{loss}: Heat amount loss happened through the glass, under part and sides of the collector case.

Thus,

$$Q_w = Q_{fall}^{direct} \cdot K_{enter}^{direct} + q_{fall}^{diffuse} \cdot K_{enter}^{diffuse} \quad (5)$$

where,

Q_{fall}^{direct}: Direct solar radiation amount falling on the collector surface;

K_{enter}^{direct}: General constant taking into consideration direct solar radiation entering inside of the collector;

K_{enter}^{direct}: General constant taking into consideration direct solar radiation entering the collector surface;

q_{fall}^{dif}: Diffuse solar radiation amount falling on the collector surface;

K_{enter}^{dif}: General constant taking into consideration diffuse solar radiation entering surface of the collector.

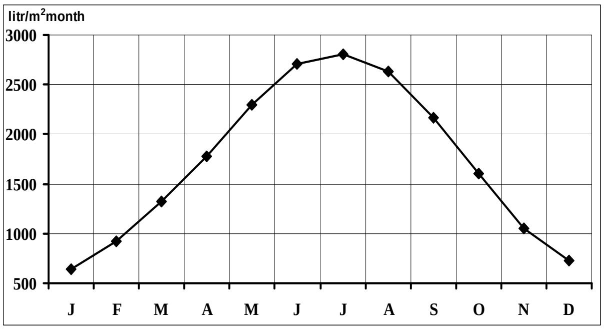

Figure 2. Productivity dependence of the flat solar collector on the month of the year which was tested in open air of Absheron peninsula

From the figure that is clear that on the month of the year in each m^2 of the flat solar collector productivity is the highest in summer months. And the lowest showings are observed in winter month. Maximal productivity is in July, approximately it reaches 2850 liter in each m^2. Minimal productivity is in January that reaches to 642 liter. This curve was obtained at the result of the experiments carried out in fair weather.

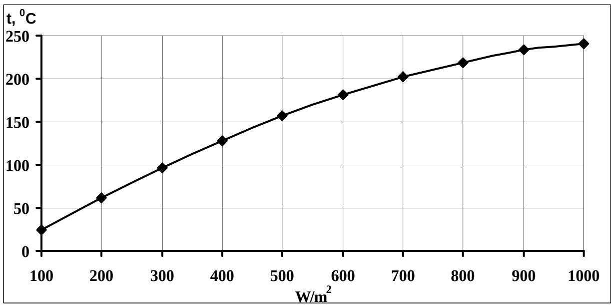

Figure 3. The dependence of the absorber surface temperature in the solar collector on solar radiation

So, by using this method average monthly and average annual productivity for all kind of flat solar collectors having different technical and energy parameters may be determined. Some experiments have been carried out for defining the temperature of the selective surface covered on the absorber in the solar collector. The experiments were mainly done at 100-1000 W/m^2 solar radiations more than once.

As seen from the figure temperature increasing happens due to the curve. From 900 W/m^2 solar radiations it is obvious that the temperature increasing becomes stable.

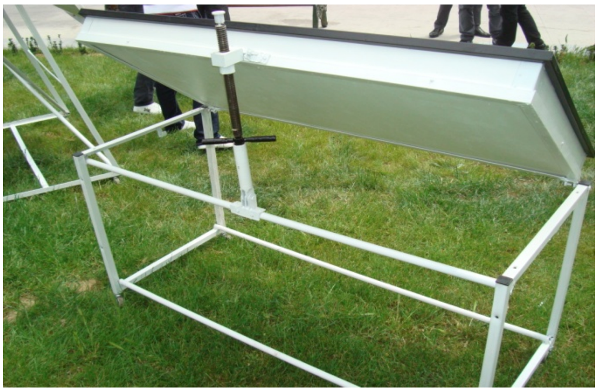

Figure 4. General view of the flat solar collector's sun tracking systems

In order to determine maximal productivity both azimuthal and zenithal sun tracking systems were mounted at the experimental plant (Figure 4). Azimuthal system has 360^0 rotation possibility. Zenithal system can act between $0\text{-}85^0$ intervals. All experiments were realized in Absheron peninsula where the plant was located (40^0 22'N latitude and 49^0 50'E longitude). For carrying out experiments the solar collector was installed at 40^0 angle.

Then by using sun tracking systems realization of experiments were continued. The obtained results have been compared. It was determined that, when solar collector works with sun tracking system the energy plant has 30-35% more productivity than ever. Because, while sun rays fall, perpendicularly onto the surface of absorber high effectiveness can be obtained.

III. RESULTS AND DISCUSSIONS

Finally, the results from the technical and economical calculations completed for flat solar collector in Absheron peninsula of Azerbaijan prove that to revive and solve these problems take much more technical and financial support or expenditures. That is why preventive measurements are to be realized, the solar energy potential should be applied in the oil industry for energy consuming processes.

According to the technical and economical approaches, flat solar collector production in local condition is cheaper than purchase of technical insufficient and economical unbeneficial collectors from different countries (especially Turkey and China). If income-generating production of the flat solar collector is carried out in the local condition, this might bring economical advantage and give opportunity to produce efficient plants from technical and energy point of view.

Because the sale price of imported goods automatically becomes higher due to the taxes and the interest of seller. The imported manufactures' excess expenses depend on various causes including taxes, transportation, gaining interest. Unfortunately in the case of estimating process the flat solar plants' energy and technical properties are not taken into consideration. The traditional energy sources usage in oil industry for energy consuming technical procedures is redundant energy consumption.

Though venal cost of thermal energy and electricity in Azerbaijan is suitable to utilize them, but their application is hazardous for environment and forms additional expenditures for solving these ecological problems.

Technical, thermal-energy and economical perspectives of the presented flat solar plant are characterized as follows:

- The materials for the separated parts of the solar plant is easy findable;
- The working condition and work force for the flat solar plane production exist;
- This plane possesses sample construction for building-up;
- Transportation of the plane is possible;
- The flat solar collector has double sun tracking systems;
- Climatic opportunities let the plane to be used in oil industry and in any field of the life;
- Heat loss in the plant is in minimum level;
- Economical beneficial energy plane's payback period is too short and profitable in comparison with others;
- Energy effective flat solar energy plane's exploitation period is longer than the imported productions from other countries in comparison;
- Annual income by economy of the fossil fuels (due to the replacement of traditional energy sources by solar energy potential) is enough;
- Reduction of the redundant expenses being used for solving ecological problems;
- The flat solar collector can prevent the environment from being damaged.

All above mentioned technical, thermal-energy, ecological, economical and climatic parameter indexes show that the presented flat solar plant projecting for manufacture is advisable. In order to develop these parameters and increase energy effectiveness, the combine heating system for the industry and life has been projected. Into this power-engineering system, auxiliary wind plant and the flat solar plane together.

These indexes have been taken into consideration for the local utilization, so for local or internal market. Of course developments of the necessary parameters of this energy plant its production and export can be realized for the external market in order to apply in oil extracting countries in oil industry or any field of the life. While summarizing the research result and discussion the experimental showings of the flat solar energy plane has been given in follow on months at the Table 1.

IV. CONCLUSION

While summarizing the research I have come into conclusion that this solar collector is effective for heating systems and hot water supply to the obtained results. Besides, the solar collector can be applied in sea water desalination process in the form of solar steel. Due to the results obtained from the carried research, I've come to the following conclusions that if the above mentioned flat solar collector is applied, then it is possible to realize the following:

- To save additional expenditures for electricity in oil fields for energy consuming processes for a year;
- To save odd expenses in oil fields for energy consuming processes for a year;
- To save excess outlays for Mazut for a year;
- Decreasing of crude oil usage can be realized;
- Reduction of superfluous outcomes for ecological damages;
- Realization of economical beneficial local flat solar collector production;
- Increasing of the technical facilities of the flat solar collectors;
- Enlargement of the solar collector local market in the Azerbaijan;
- Provision of the families with cheap, effective solar collectors who has little salary;
- Opening new work places and plants for production of such collectors;
- Supplying thermal-energy effective and durable flat solar collector to the local markets instead of Chinese or other productions;
- Organization of money turnover within the country due to the vendees' order and sellers' offer.

All these conclusions lead to the great economy in the state budget. The individual or combined application of the flat solar collectors is possible to realize the missions noticed in the conclusion. The exploitation is economically and technically more profitable for oil industry fields and also the population living in houses.

Table 1. The experimental results of the flat solar collector (June-July-August 2011)

Date	Direct solar radiation, kcal/m^2 day	Average		Selective surface temperature, ^{0}C	Heat-carrier temperature, ^{0}C	Efficiency. %
		Air temperature, ^{0}C	Wind speed, m/sec			
June 2011						
1	6780	32	2,5	174	70,6	0,71
5	6860	33	2,7	178	72	0,71
10	6915	34	2,4	180	72,8	0,72
15	7050	35,5	1,0	182	73,1	0,73
20	7190	35	1,1	185	74	0,74
25	7220	36	1,0	190	75,4	0,75
30	7238	36	1,5	196	76	0,75
July 2011						
1	7270	36	2,1	198	76,5	0,75
5	7369	38	2,8	210	77,1	0,75
10	7590	38,1	3,5	223	78,9	0,76
15	7585	39	2,0	235	80	0,77
20	7592	39	1,2	238	80,2	0,78
25	7654	41	1,1	245	81,1	0,78
30	7650	40,4	1,5	242	80	0,77
August 2011						
1	7610	39,6	1,4	243	80,1	0,77
5	7598	39,5	2,0	238	79,5	0,77
10	7300	39	1,8	232	78	0,75
15	7120	38,6	2,4	222	78	0,75
20	7034	36	3,3	201	76,4	0,74
25	6865	35,8	3,8	182	75,2	0,73
30	6680	33,7	3,5	178	73,3	0,72

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BIOGRAPHY

Fuad F. Mammadov was born in Baku, Azerbaijan in 1981. He received Bachelor degree in 2001 and Master degree in 2003 from Azerbaijan Technical University, Baku, Azerbaijan on «Thermal Transfer, Non-Traditional and Renewable Energy Sources and Plants» profession. He received Ph.D. in 2007 on «Parabolic trough Solar Energy Plant for Solar Energy Application in crude Oil Treatment» theme. He has more than 60 publications in the international journals including 7 certifications of authorship and two books including "Solar Power Engineering Terms in Azerbaijan, Russian, English, German, French, Spanish, and Italian" and also "Solar Energy Use in Azerbaijan and Modern Solar Energy Plants", also a teaching aid on renewable energy sources and some energy maps. His research interests are as technical, ecological and economical estimation of renewable energy sources, solar, wind and other renewable' application in different technological processes in industry. At present, he is the Associate Professor at Azerbaijan State Oil Academy, Baku, Azerbaijan. He trains specialists on renewable energy sources (solar, wind, wave energy, hydrogen, etc.) for oil industry. He is also the author of more than 20 solar and wind energy plant with new constructions and application fields. He preferred progressive sun tracking systems for solar energy plants which are utilized in these equipments. He is selected Since 2008 as a member of the International Steering Committee of WREC being held by WREN.