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# DEVELOPMENT OF A MULTIPURPOSE SOLAR ENGINE

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A hot air engine has been developed that directly made use of solar energy for its operation. A 1.54 $m^2$ reflecting parabolic stainless steel concentrator provided solar energy enough to run the engine. The efficiency of the engine with air cooled sink was 40%. The engine worked for six to eight hours on every clear day in all seasons without any arrengements for the storage of solar energy.

## INTRODUCTION

The present energy crisis with the depletion of fossil and other conventional sources and the rapid increase in the energy demand has made the use of solar energy imperative. In Pakistan, on the average, 1000 watts of solar energy is incident on each square meter for six to seven hours every day (Shah, 1976). Many solar devices have been designed to perform particular functions like water heater, cooker, kiln, generator etc. A solar engine is a very useful multipurpose device which can do almost anything. Electric motors are no doubt very popular but in the remote areas where there is no electricity available, these are of no use. The other non-electric engines like internal combustion engines having their energy source inside the working cylinder, require special type of fuels. Hot air engines have exterior energy source and virtually any type of energy source can be utilized to run them. These are in fact potential candidates for harnessing solar energy, These are little bit bulky and have limited speeds, But, these have some significant advantages as well. These are light, simple and have relatively noiseless operation. These requir no valves or exhaust and thus do not clatter or bark. Overall thermal efficiency of hot air engines is comparable with that of internal combustion engines (Donkin, 1958). Leonord (1958), Wrangham (1942), and Mooney (1958) have described some typical regenerative hot air engines, Because of its prospective nature other nesigns are also being tried in various countries. Hull (1984) worked on reciprocating solar engine in which concentrated sun beam was directly absorbed by small particles within the working cylinders. With improved heat resistant materials and better design of these engines, solar enetgy can be effectively utllized.

## MATERIAL AND METHODS

A small hot air engine was assembled from locally manufactured components. The engine directly utilizes solar radiation energe for its operation. It works on the Stirling cycle. The effects of irreversibility are less in it than in the Cornot cycle (Keenan, 1957). The Stirling cycle in idealized form is shown on P-V and T-S diagrams in figure 1. The cycle consists of two isotherms joined by two regenerative isometric processes. Heat is absorbed from the source during isothermal expansion from $v_1$ to $v_2$ at a higher temperature $T_1$ and is rejected to a sink at a lower temperature $T_2$ during other isothermal compression from $v_2$ to $v_1$. The two isochoric processes (2-3) and (4-1) with the help of regenerator permit reversible heat flow from and to the gas.

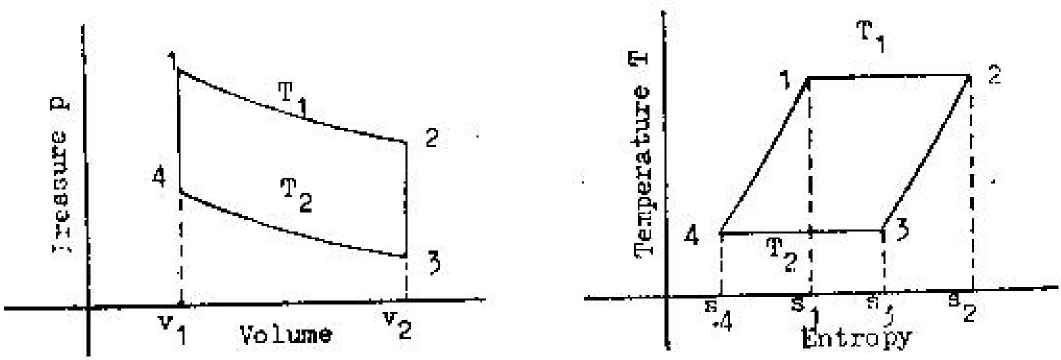


**Fig. 1. Stirling cycle on P-V and T-S diagrams.**

A regenerator is a thick pack of fine copper gauze having infinite or very large heat capacity compared with that of the gas. It acts as a temporary storage of heat.

The thermal efficiency of the cycle for an ideal regenerator is

$$1 - Q_2/Q_1 = 1 - T_2/T_1.$$

But, if the efficiency of the regenerator is e, then the efficiency of the cycle will be

$$\frac{R\,(T_1-T_2)\,\log\,(v_2/v_1)}{RT_1\,\log\,(v_2/v_1) + (1-e)\,Cv\,(T_1-T_2)}$$

where Cv is the specific heat of the gas at constant valume. In practice e is about .8 to .9 (Robinson and Dickson, 1961).

A reflecting parabolic concentrator, fabricated in the Department of Physics was used to focus solar radiations incident on 1.54 $m^2$ on to a smaller area. The solar energy thus accumulated achieved on the average temperature of about 200°C. The focus of the concentrator was treated as heat source for the engine. Various types of heat transfer chambers and the glass enclosures were designed and tested. Finally a combination of thick blackened copper cyclinder and brass gauze was found suitable to absorb enough heat from the round glass enclosure to run the engine, when placed at the focus of the concentrator. Certain modifications were also made in the design of the concentrator to keep a record of the sun track and to hold the engine firmly at the desired position.

A thermocoupie in conjection with a pyrometer was fixed in the heat transfer chamber to observe the working temperatures of the engine.

## RESULTS AND DISCUSSION

The average temperature of the heat transfer chamber achieved with the help of parabolic concentrator and its variation during day time in the months of May-June, Sept.-Oct. and Nov.-Dec. during 1985 is shown in figure 2. The engine started its operation above 220°C temperature of the chamber, The warm up time of ths engine was up to half an hour.

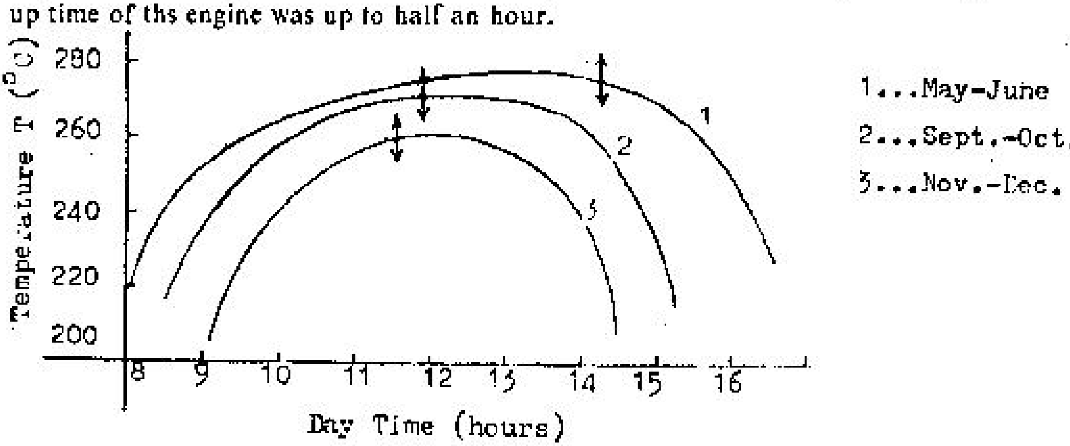


Fig. 2. Variation of average maximum temperature of the heat chamber with time.

The figure 2 shows that the temperatures of the chambers were above 220°C for six to eight hours in all seasons of the year. Thus the engine could work for about six hour on every clear day without the need of any storage arrangements of the solar energy. The figure 3 shows the revolutions per minute of the engine against the temperatures of the chamber. The sink which was air cooled maintained a steady temperature of 50°C.

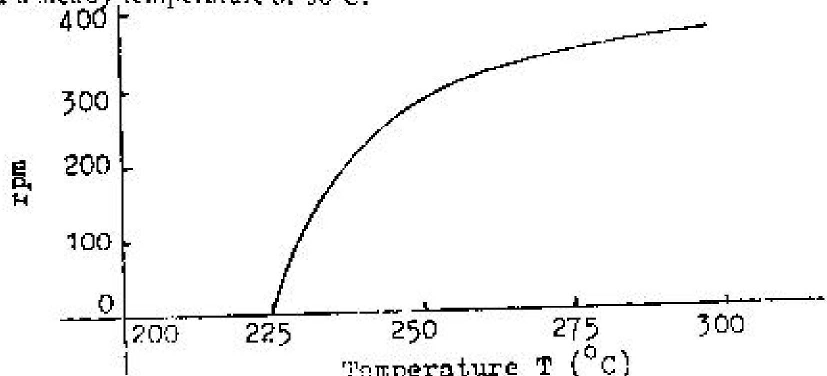


Fig. 3. Engine revolutions per minute against chamber temperatures.

The efficiency of the engine between 270°C and 50°C working temperature limits is 40%. A high speed six volt generator attached to the engine demonstrated one of its many applications. It produced maximum 5.9 volts. Actually a low speed dynamo was more suitable for this type of engine with limited speed for optimum generation of electric power. The voltage generation versus revolutions per minute of the engine is shown in figure 4.

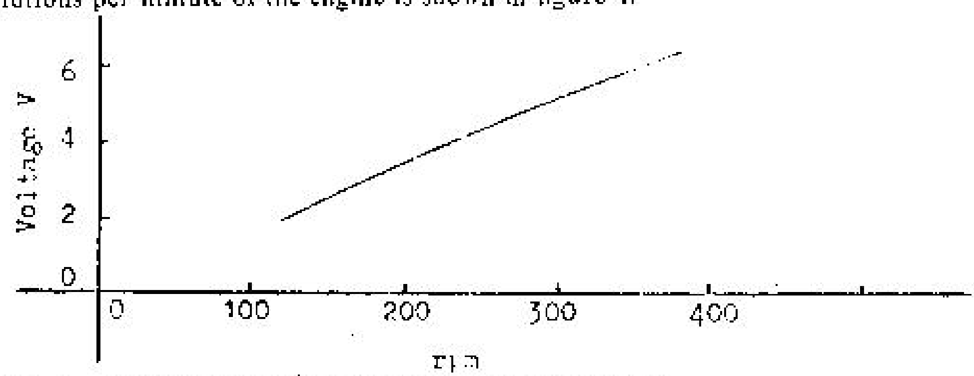


Fig. 4. Voltage generation againt speeds of the engine.

The versatility of the solar engine had been further projected with the addition of a closed cycle inclined water lift unit to the engine. The unit lifted water to 30 cm height. The pump discharged half litre water per minute when it was turned at the rate of 100 revolutions per minute.

The generation of electric power by the engine insead of by the imported solar cells can save foreign exchange. The curves in figure 2 show a very small change in the maximum temperature of the working chamber during the year, so it does not affect the operation of the engine. It is because the concentrator can always be held perpendicular to the sun whereas the variation in the inclination of solar radiations on the surface of earth produces significant effects on the temperature of the weather. The slight fall in the temperature of the chamber in winter is due to the higher dissipation losses in the cold environments. The curves also show a decrease in the daily working hours of the engine in winter due to shorter day length. The water need for irrigation also declines in this period. The performance of the solar engine is thus particularly suitable for cattering water requirments for agriculture. The tests of the engine are very encouraging. Abigger module based upon tne principle of the present model hopefully will have the potentialities and capabilities of an efficient commercial venture.


## ACKNOWLEDGEMENTS

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