SOLAR ENERGY

Development of a minimum maintenance solar pump

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ABSTRACT

Recent efforts at the University of Science and Technology (UST), Kumasi, have resulted in the successful development of a Minimum Maintenance Solar Pump (MMSP) from locally available materials. The design employs 202.5 litre (45 gallon) oil drums reinforced with 12.7mm (0.5 in) steel pipes. Two prototypes based on this design have been tested at UST and Brace Research Institute (BRI), Montreal. The maximum average temperature attained in the UST prototype was 84°C with no water being pumped while the BRI prototype pumped 158 litres (79% of total capacity) with the bottom of the drum reaching 96°C. The volume of water which remains in the drum after a previous operation has a great influence on the maximum temperatures attained by the drum and the test results indicate that this residual water should be kept at a minimum of about 1 litre.

Keywords: solar pump, minimum maintenance, residual water, tank temperatures.

INTRODUCTION

The Minimum Maintenance Solar Pump (MMSP) is a solar water pumping system which operates on a diurnal cycle with solar heating and nocturnal cooling. The MMSP has no moving part, making it the simplest solar water pump ever to be developed[1]. The MMSP concept was first suggested by Prof. R. Bernard of Lyons University, France. Prof. Bernard's first MMSP prototype[2] was built in France where the availability and quality of materials are much higher than most developing countries. The prototype employed a 3mm-thick pressure vessel with nickel oxide selective coatting and triple-glazing and it delivered about 85% of its total pumping capacity at a pump head of 7m . Subsequently two unsuccessful attempts were made in Canada to construct the MMSP using materials readily available in developing countries[3,4].

More recent efforts at the University of Science and Technology (UST), Kumasi, have resulted in the successful development of the MMSP from locally available materials. The UST design employs 202.5 litre (45 gallons) oil drums which are very common in Ghana and can be purchased from almost any petrol filling station.

PRINCIPLE AND OPERATION

The MMSP consists of a metal tank (or drum), an insulating box, a transparent cover, some piping and two valves as shown in [Figure 1]. The tank is painted mat black and placed inside an insulating box with a transparent cover to allow solar radiation to enter. There would usually be a small quantity of water in the tank, left over from a previous day's operation so that, at the beginning of the cycle, the tank would contain some residual water and air.

During the day the tank absorbs solar radiation and heats up. The air in the tank expands and some of it escapes through the suction pipe. As the tank continues to heat up, the residual water evaporates and the water vapour helps to evacuate the air which should be seen bubbling in the water source at the lower end of the suction pipe. At the end of the afternoon when the solar radiation diminishes, the tank cools off and the bubbling stops.

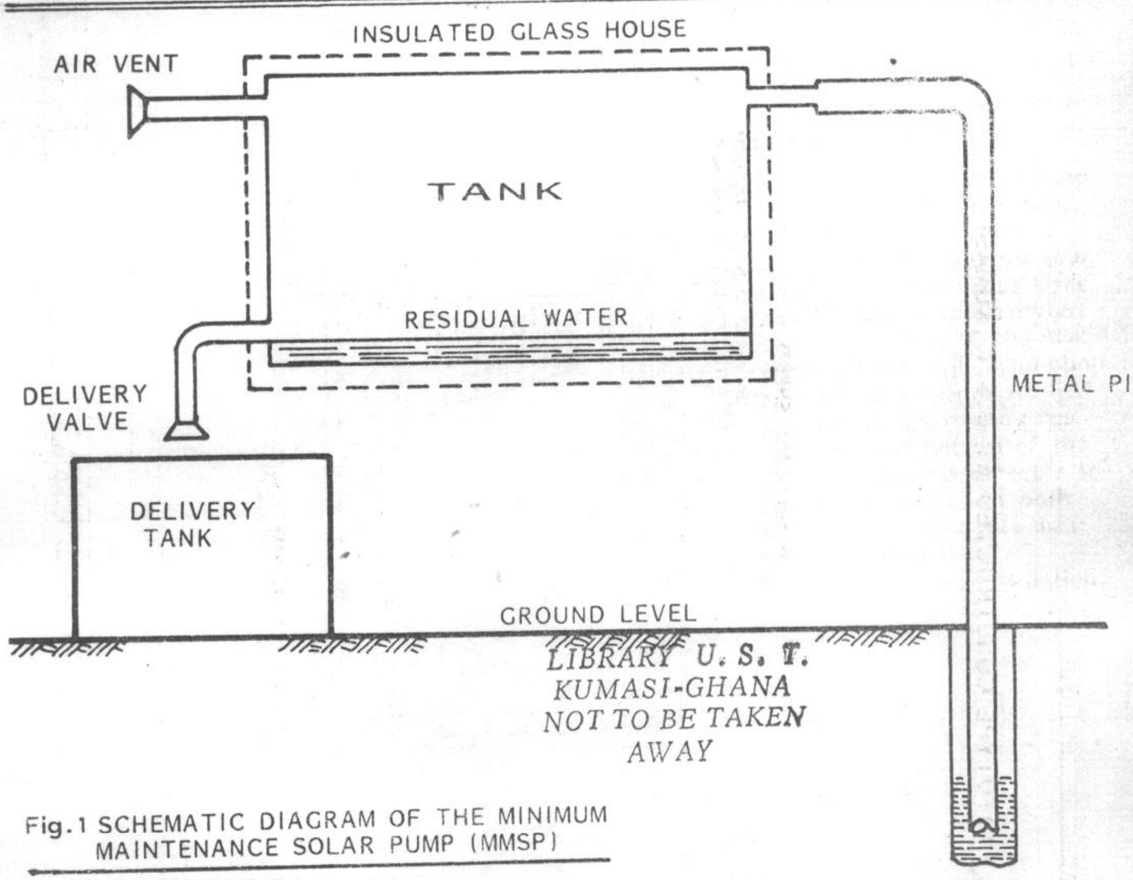

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Fig. 1 SCHEMATIC DIAGRAM OF THE MINIMUM MAINTENANCE SOLAR PUMP (MMSP)

During the night condensation of water vapour takes place and water is slowly drawn up the pipe. The following morning the user opens the air vent and drain valve to allow the pumped water to flow either into a storage tank or directly into an irrigation system. The tank is designed and placed inside the box in such a way that there is always some residual water after the tank is drained. All the the user then has to do is to close the drain valve and air vent for a new pumping cycle to start.

The performance of the MMSP is highly dependent on the maximum temperatures attained by the tank. The higher the temperatures attained by the tank the more air is evacuated from the system and hence the larger the volume of water pumped.

PROTOTYPES

Two MMSP prototypes based on the UST design have been constructed and tested, one at UST, Kumasi, and the other at Brace Research Institute (BRI), Montreal, Canada. Sectional views of the UST prototype are presented in Figure 2 and a sectional view of the BRI prototype is also presented in Figure 3. Both prototypes employ a 202.5 litre drum reinforced with 4 equally spaced 12.7mm steel pipes welded longitudinally onto the drum. The drum is painted mat black and lies within an enclosure with reflective surfaces.

The UST prototype was originally designed to have triple-glazing (one outer perspex sheet and two inner glass sheets) with an aperture area of $0.93m^2$. The glazing was made horizontal because of the nearness of Kumasi (lat. 6°43'N) to the equator. The UST prototype was installed at about 2m head and during the first few tests the temperature at the top of the tank rose to about 130°C causing the lower glass sheet to break. This occurred on two occassions and all the remaining tests were therefore conducted with double glazing.

The BRI prototype also employed double glazing (two glass-sheets) with

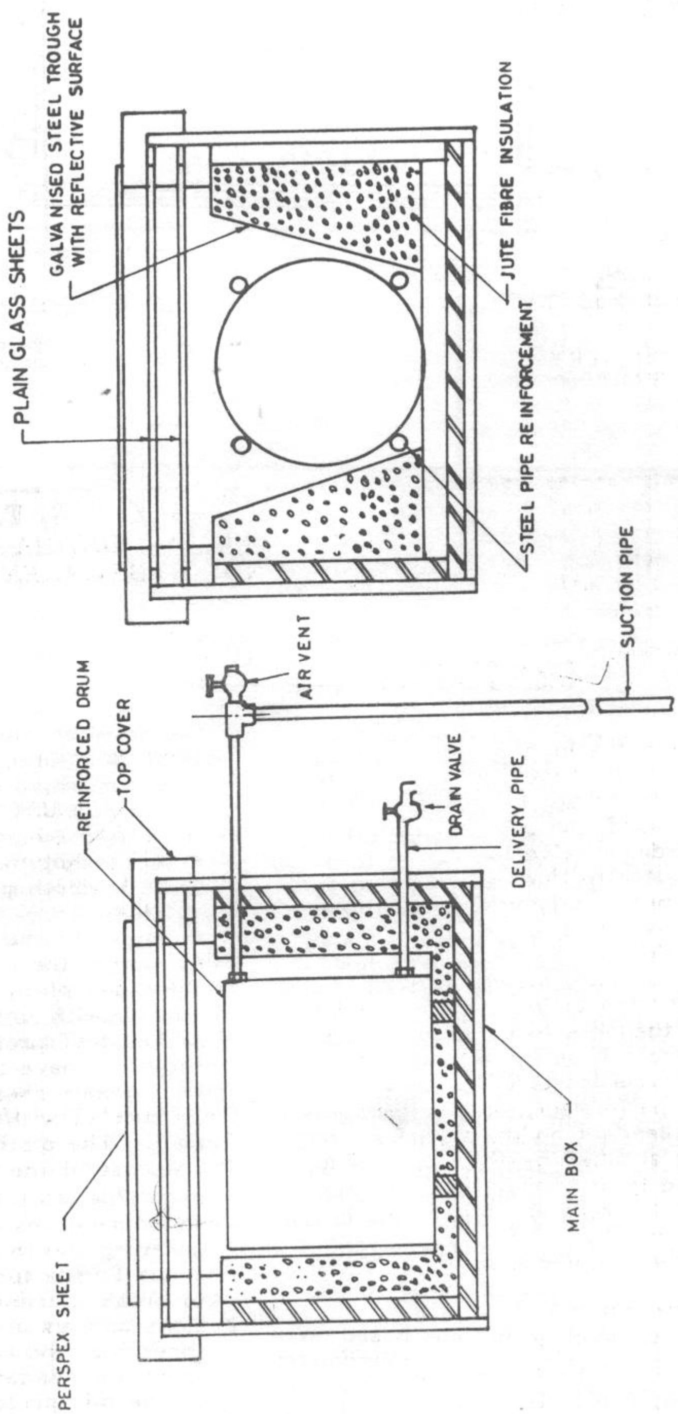

Fig.2 SECTIONAL VIEWS OF THE MMSP PROTOTYPE CONSTRUCTED AT U.S.T., KUMASI

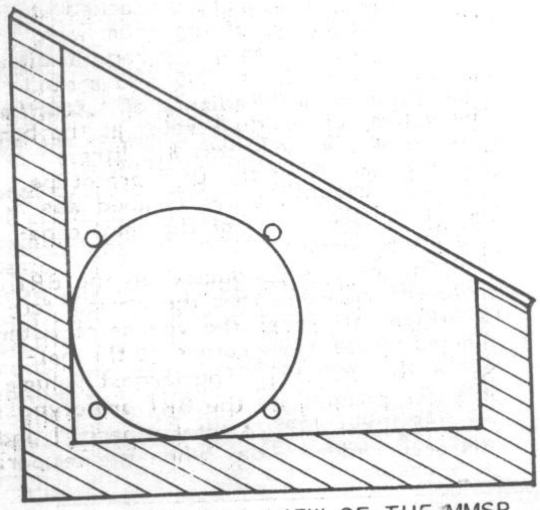

Fig.3 SECTIONAL VIEW OF THE MMSP PROTOTYPE CONSTRUCTED AT BRACE RESEARCH INSTITUTE MONTREAL

an aperture area of 1.07m². The glazing was inclined at 30° to the horizontal because of the high latitude of Montreal (46°4'N). The prototype was installed at a head of 3.5m.

TEST RESULTS

Results from two tests conducted on the UST and BRI prototypes are presented in Figure 4 and Figure 5 respectively. In the UST set-up four copper-constantan thermocouples were attached to points equally distributed around the central portion of the MMSP drum and connected through a junction box to a digital thermometer. At BRI two copper-constantan thermocouples attached to the top and bottom of the MMSP drum were connected directly to a Digistrip chart recorder. In both cases an additional thermocouple measured the ambient temperature.

In Figure 4 global solar radiation,

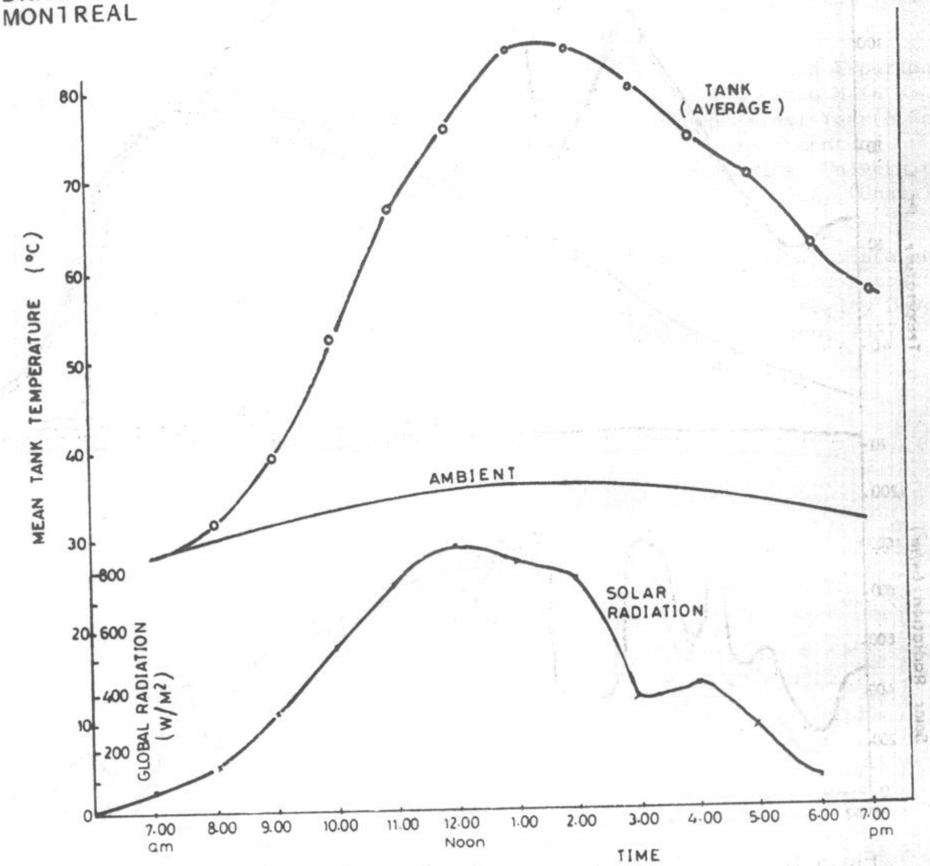

Fig.4 TYPICAL EXPERIMENTAL RESULT OBTAINED WITH THE MMSP PROTOTYPE AT UST, KUMASI

ambient temperature and average temperature of the drum in the UST prototype are plotted against time of day. The maximum average temperature of the drum was about 84°C with an average ambient temperature of 30°C and a maximum solar radiation of 850W/m². The amount of residual water in the drum at the start of the experiment was 17 litres. The system failed to pump any water because of the large volume of residual water which resulted in the rather low temperatures attained by the drum[5].

In Figure 5 global solar radiation, ambient temperature and temperatures at the top and bottom of the drum in the BRI prototype are plotted against time of day.

Maximum temperature reached at the top and bottom of the drum were 122°C and 87°C with an average ambient temperature of about 23°C and a maximum global solar irradiance of 1,080W/m² The volume of residual water at the beginning of the cycle was 8.5 litres, half the amount in the UST prototype, and the volume of water pumped was 100 litres (about 50% of the total capacity of the drum).

Other tests conducted on the BRI prototype revealed that the critical factor which influences the volume of water pumped is the temperature at the bottom of the drum[6]. The largest volume of water pumped by the BRI prototype was 158 litres (79% of total capacity) and this occurred on a day when the tempera-

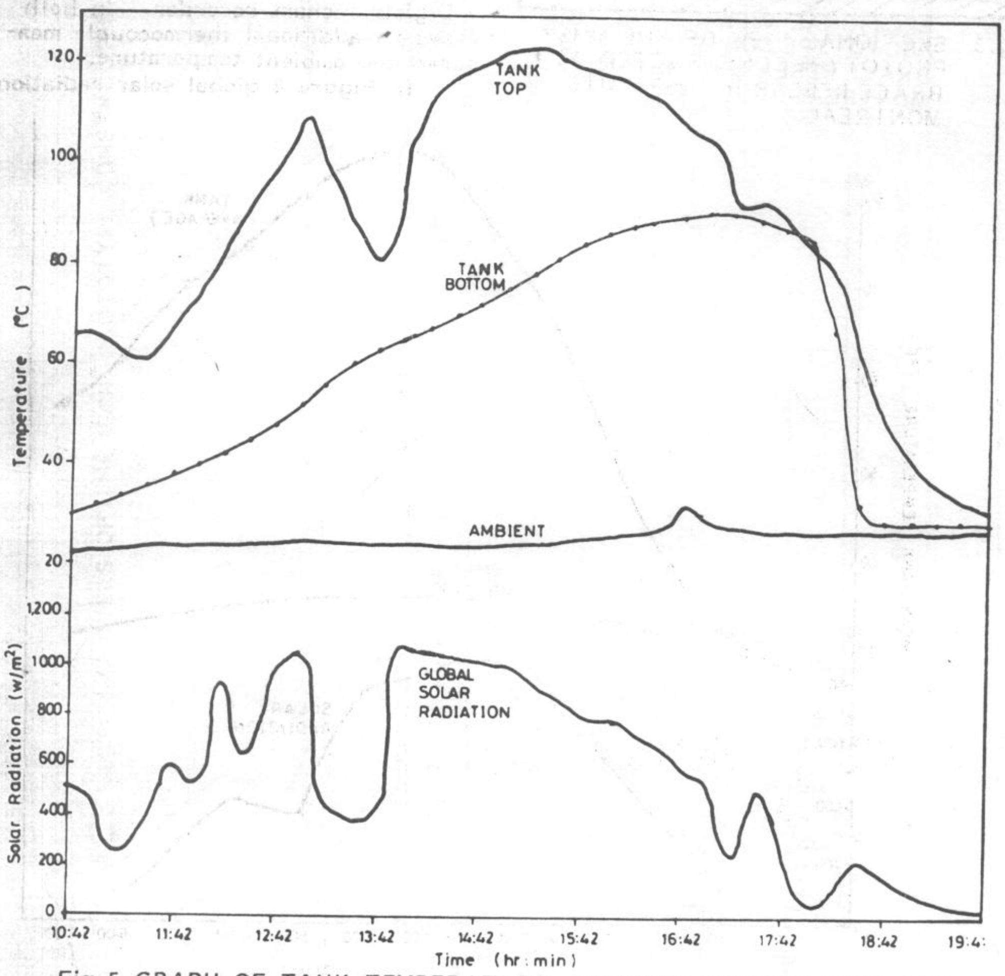

Fig.5 GRAPH OF TANK TEMPERATURE, AMBIENT TEMPERATURE AND GLOBAL SOLAR RADIATION vs TIME FOR MMSP PROTOTYPES AT BRACE RESEARCH INSTITUTE

ture at the bottom of the drum rose to 97°C with 1 litre of residual water. Thus, the temperature at the bottom of the MMSP drum depends very much of on the volume of residual water.

The poor performance of the UST prototype was due to the large volume of residual water (17 litres) and this problem will be addressed in future tests. A special hole for the delivery pipe may have to be fabricated as close as possible to the bottom of the drum so that only about 1 litre of water remains when the tank is drained. Alternatively, a syphon could be permanently installed inside the drum to give the same effect.

CONCLUSIONS

A design of the MMSP, which employs reinforced 202.5 litre oil drums, has been successfully tested. The test results indicate that for optimum performance of the system the residual water in the drum should be reduced to a minimum of about 1 litre.

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