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EFFECT OF COVER SLOPE ON THE THERMAL PERFORMANCE OF THE BASIN-TYPE SOLAR STILL

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تأثير ميل الغطاء على الأداء الحراري لمقطرة شمسية من النوع الحوضي

خلاصة - في هذا البحث ، تمت دراسة تجريبية لتأثير درجة ميل الغطاء الشفاف على الأداء الحراري لمقطرة أحادية الميل من النوع الحوضي تعمل بالطاقة الشمسية . ولهذا الغرض تم تصميم وبناء أربعة مقطرات ذات أبعاد ومواصفات متماثلة ولكنها تختلف فقط في درجة ميل الغطاء الزجاجي ، حيث تأخذ درجة ميله في المقطرات القيم ١٠° ، ١٥° ، ٢٠° ، ٣٠° . وقد أخذت القراءات تحت ظروف التشغيل العادية بإجراء إختبارات موزعة على مدار عام كامل . وبتحليل هذه القراءات أظهرت النتائج أن المقطرة التي ميل غطائها ١٥° قد سجلت أعلى إنتاجية وأكبر كفاءة حرارية على مدار العام .

ABSTRACT - In the present work, the effect of transparent cover slope on the thermal performance of the single-sloped basin-type solar still has been experimentally investigated. For this purpose, four stills with identical dimensions and specifications have been fabricated. The only difference between them is the glass cover slope angle, which has the values of 10°, 15°, 20° and 30° for the stills. The experimental data are collected from outdoor tests scattered over a complete year. Results have shown that the still with cover slope 15° has the best productivity and thermal efficiency all over the year.

INTRODUCTION

Conversion of saline water to fresh water by solar energy has become one of the most important application of solar energy technology, since it is an efficient and low cost thermal process. Moreover, it is a suitable option for the new societies in arid areas, specially after the sharp increase in the prices of the fossil fuel operated desalination plants. In practice, there are many different designs for the solar stills. The basin-type solar still is seen to be the most common and practical design. The thermal performance of a solar still may be influenced by the climatic conditions, operational variables and design parameters. The basin-type solar still main design parameters are; the still shape, orientation, fixation, brine depth in the basin, number of covers and the cover slope. Several investigations have been carried out to study the effect of design and operational parameters on the still performance [1-5]. However, researches concerning the effect of cover slope angle on the still performance are seen to be little and insufficient.

In fact, if the cover slope angle is small, the condensate slipping on the lower cover surface will be slow. In this case,

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the condensate will be either re-evaporated again or fallen back to the basin, which reduces the still productivity. Large slope angle increases the path travelled by the condensate to the collection trough, and increases the chance of re-evaporation. Between these two limits, there exists an optimum slope angle. which results in a maximum still productivity and thermal efficiency. Sorour et al [6] have reported that the still with cover slope angle of 16° has the highest productivity during the month of November. The experimental data collected by Abdel Salam and co-workers [7] have shown that the stills with cover slope angles of 5° and 30° have recorded a maximum coefficient of performance during the summer and winter respectively. Shafiey [8] reported that the still with cover slope angle of 30° has recorded the highest productivity during the autumn of 1981.

In general, the previous results in this field are seen to give insufficient annual information on the still performance. The basin-type solar still has a fixed cover. Therefore, an optimum cover slope angle which yields a maximum annual productivity should be decided. This is the object of the present experimental work.

THE SETUP AND EXPERIMENTAL PROCEDURE

The setup consists of four single-sloped simple basin-type solar stills with identical dimensions and specifications. The basin of each still is a rectangular of 0.8 x 1.2 m. The stills are fixed such that their glass covers are facing the south. The stills differ only in the cover slope angle, where it takes the value of 10°, 15°. 20° and 30° for the stills. A cross sectional view of one still and a photograph of the setup are shown in Fig.1.

All stills have the following common specifications :
Ordinary window glass cover (3 mm thick).
Height of the lower edge = 8 cm.
Depth of water in the basin = 3 cm.
Blackboard coated galvanized iron sheet inner liner(0.8 mm thick).

The experimental work is carried out at Mansoura University, Egypt (latitude 30°N). The tests are conducted outdoors with at least two days in each month over a complete year, using the ordinary tap water. The setup is suitably instrumented to measure the temperatures at different points, the stills productivity and the meteorological variables. The temperatures are measured by copper-constantan thermocouples and the productivity is measured by collecting the yield in a scaled jar. Measurements are taken from about 9 a.m to 6 p.m with a regular time interval of 1 hour. The daily productivity of each still is measured in all experiments. The performance of each is also examined during a full day (24 hours).

RESULTS AND DISCUSSION

The experimental data for two selected days are given in Figures 2, 3, 4 and 5 as a sample of results. In fact, the most important temperatures that affect the still performance are the basin water temperature and that of glass cover. The still productivity is proportional to the difference between these two temperatures [9]. Figure 2. shows the variation of basin water temperature with time for all sills in the selected days. The variation is seen to follow that of solar radiation. The corresponding glass cover temperature is shown is Fig. 3.

The hourly productivity for each still is shown in Fig. 4. It is clear from the figure that the hourly productivity increases with time, reaching a maximum value at about 3 p.m. and then decreases gradually. The maximum differences in productivity between stills also occur at 3 p.m. The corresponding accumulated productivity increases with time, even at night as shown in Fig.5. This is because the water-cover temperature difference is maintained at an effective value during a part of the night as seen from results. To be satisfied with the experimental results, the measured productivity is compared to that calculated from the modified Duncle's equations [9] given below,

$$w = q_{ew} / \rho L \qquad m^3/hr.$$

where w is the productivity, m^3/hr,

ρ is the density of water, Kg/m^3,
L is the latent heat of evaporation, KJ/Kg,
and q_{ew} is the rate of heat transfer from water to cover by evaporation and condensation in KJ/hr, and is given by,

$$q_{ew} = 0.0088\ A\ [(T_w - T_{gi}) + (\frac{P_{sw} - P_{sgi}}{2.653\ P_T - P_{sw}})\ T_w\ ]^{1/3} (P_{sw} - P_{sgi})\ L$$

where A is the basin area, m^2,

T_w is the basin water temperature, °C,

T_{gi} is the inner cover surface temperature, °C,

P_{sw} is the saturation pressure of water vapour at T_w, N/m^2,

P_{sgi} is the saturation pressure of water vapour at T_{gi}, N/m^2,

and P_T is the total pressure inside the still = $1.013 \times 10^5\ N/m^2$,

Actual data are used to obtain the productivity from these equations. The agreement between the measured and calculated values of productivity is seen to be satisfactory as shown in Fig. 6.

On the other hand, the hourly thermal efficiency, η of each still is calculated from,

$$\eta = w \rho L / A H$$

where H is the total solar flux on a horizontal surface, KJ/m^2hr. Fig. 7. shows a plot of the hourly thermal efficiency for the stills in the selected days. The thermal efficiencies of the stills increase with time up to the sunset hour. This is because the solar radiation is decreasing faster than the productivity in the afternoon hours.

However, the instantaneous comparison between the stills may be misleading due to any quick variations in the solar radiation. Therefore, the daily total productivity for each still is collected, and the corresponding daily thermal efficiency is calculated in all experiments. These values which are based on 24 hours operation, are used for comparison between the stills. Fig.8. shows the daily productivity for each still during all experiments over the year. It can be easily seen that the still with cover slope 15°has shown the highest productivity most of the year. Out of 24 tests, it has recorded a maximum daily productivity in 15. In the other tests, the productivity of this still is very close to the best one as shown in the figure. The corresponding daily thermal efficiency for each still is shown in Fig. 9. As expected, the changes in the daily thermal efficiency follow that of the daily productivity. Therefore, the same comparison trend can be observed in the figure.

CONCLUSION

The influence of cover slope angle on the thermal performance of a single-sloped basin-type solar still has been experimentally investigated. The experiments are conducted outdoors on four solar stills with identical dimensions, but different glass cover slope angles; namely 10°, 15°, 20°and 30°. At least, two days in each month of the year are selected to perform the tests. The collected data have shown that the still with cover slope 15° has recorded the highest productivity and efficiency during about 58% of the total number of tests. In other tests, its produtivity is almost work are restricted for latitudes around 31° N.

REFERENCES

1. J. W. Bloemer, J. A. Eibling, J. R. Irwin and G. O. G. Löf," A practical basin-type solar still", Solar Energy Society Conference, Pheonix, Arizona, March 15-17, 1965.
2. H.P. Grag and H. S. Mann,"Effect of climatic, operational and design parameters on the year performance of single-sloped and double-sloped solar still under Indian arid zone conditions", Solar Energy, Vol. 18, pp. 159-164, 1976.
3. A.K. Rajvanshi,"Effect of various dyes on solar distillation", Solar Energy, Vol. 27, pp. 51-65, 1981.
4. G.C. Bandey, "Effect of dried and forced air bubbling on the partial pressure of water vapour and the performance of solar still", Solar Energy, Vol. 33, pp. 13-18, 1984.
5. Y. Assouad and Z. Lavan,"Solar desalination with latent heat recovery", Journal of solar Energy Engineering, Vol. 110/15, February 1988.
6. M.M. Sorour, M.A. Wahhab and M.M. Nasr,"Optimal design studies of basin-type solar still",4th International Alternative Energy

Conference, Miami, U.S.A, Dec. 1983.

7. M. S. Abdel Salam, N .H. Helwa, M. A. Mohamed and M. Shinkar, "Effect of cover slope and inside air volume on the performance of solar stills", 2nd Arab International Solar Energy Conference Bharain, Feb. 1986.
8. M. E. El-Shafiey, "Improved performance of solar stills", M.Sc. Thesis, Faculty of Engineering, Tripoli, Libya, 1983.
9. R.N. Morse and W.R.W Read, "A rational basis for the engineering development of a solar still", Solar Energy 12(1), 5-17 (1968).

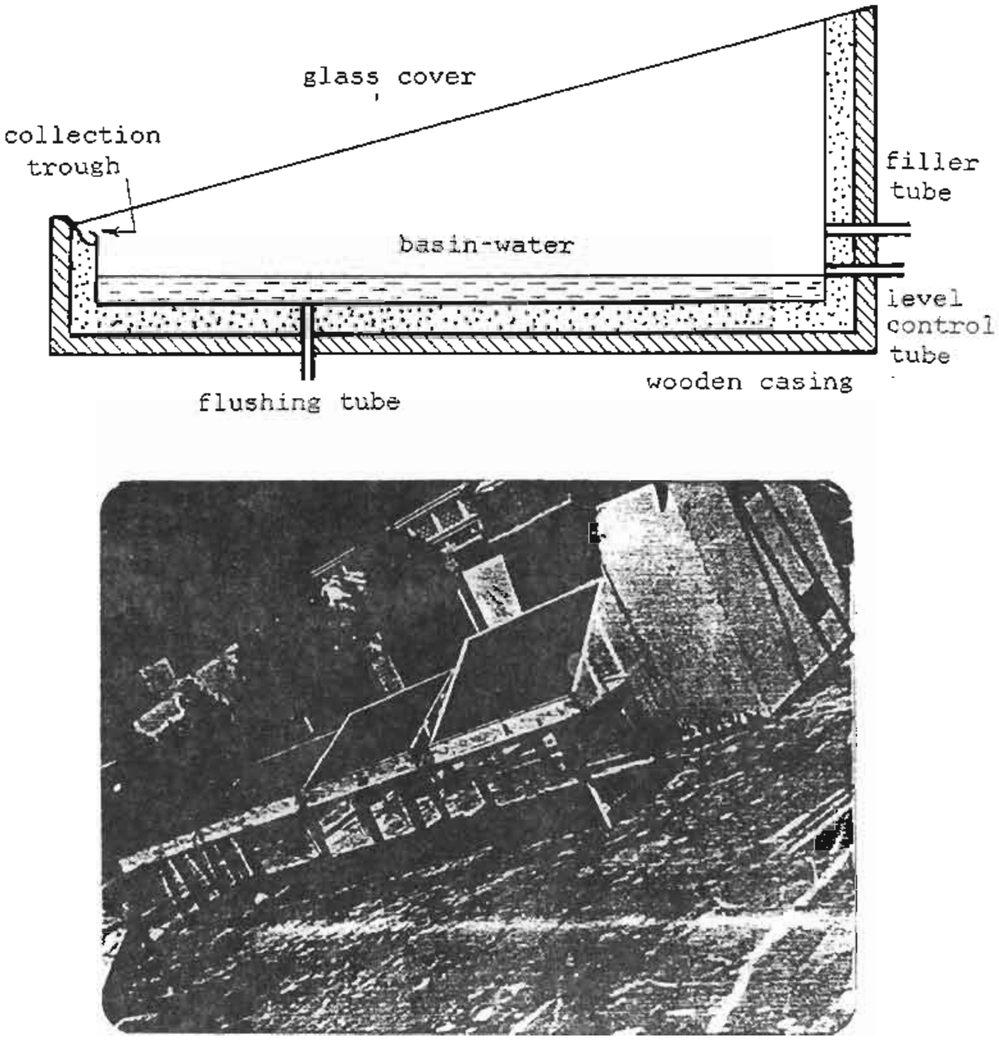

Fig. 1. A cross sectional view of one still and a photograph of the setup.

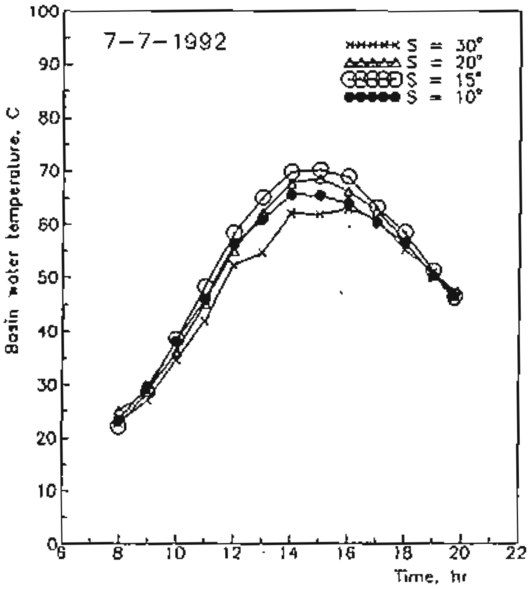

Fig. 2.b. Variation of the basin water temperature with time.

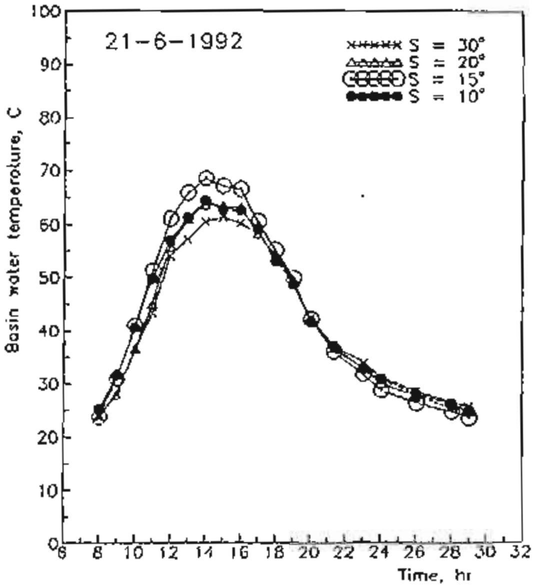

Fig. 2.a. Variation of the basin water temperature with time.

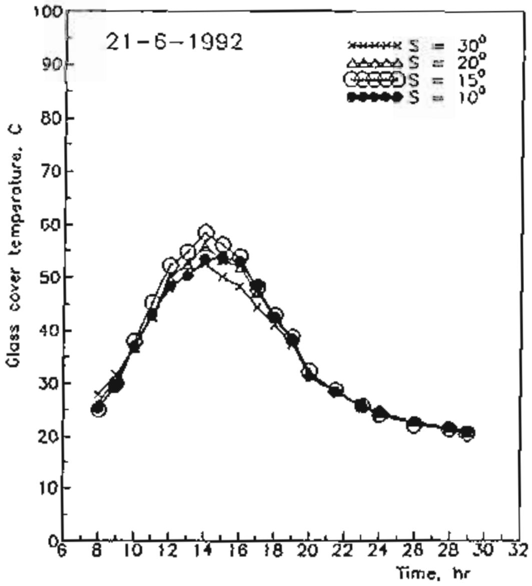

Fig. 3.a. Variation of the glass cover temperature with time.

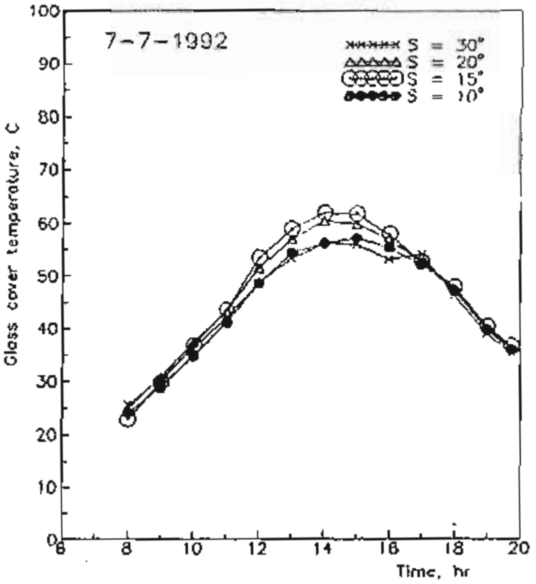

Fig. 3.b. Variation of the glass cover temperature with time.

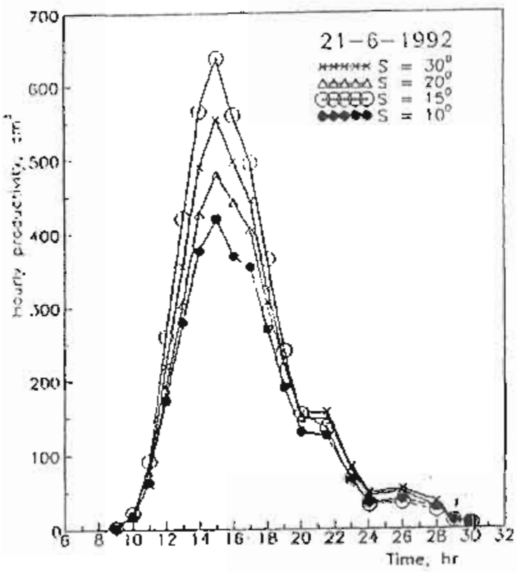

Fig. 4.a. Variation of the hourly productivity with time.

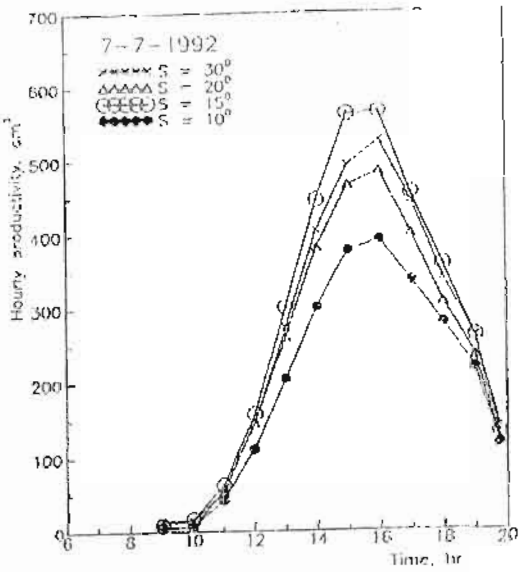

Fig. 4.b. Variation of the hourly prductivity with time.

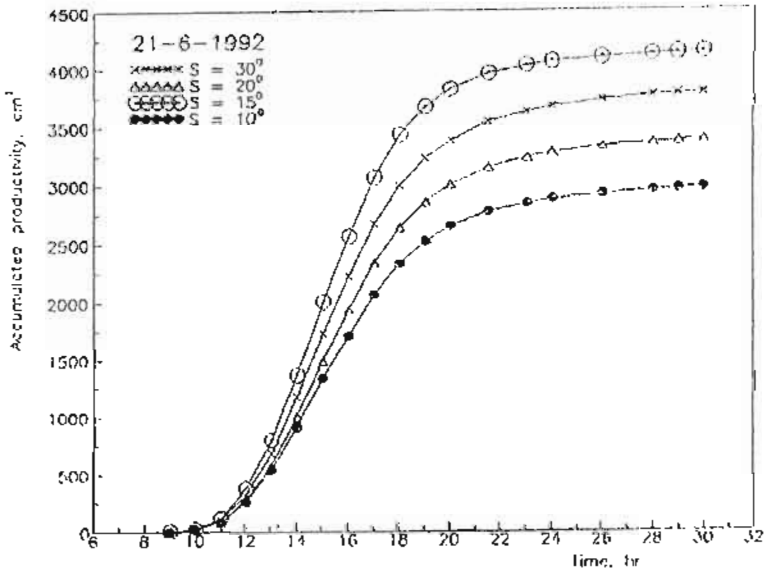

Fig. 5.a. Variation of the accumulated productivity with time.

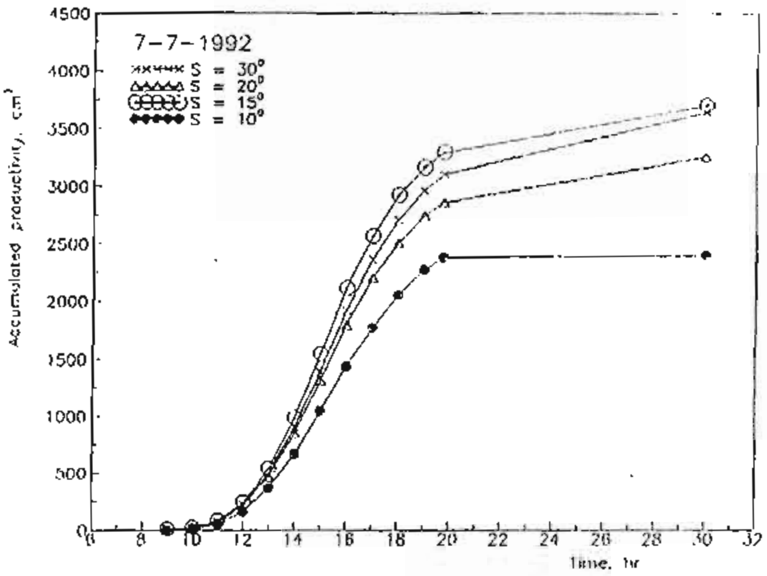

Fig. 5.b. Variation of the accumulated productivity with time.

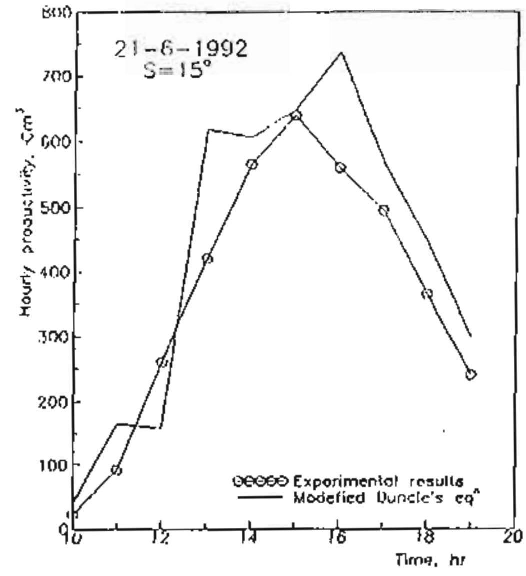

Fig. 6.a. Comparison between the measured and calculated results.

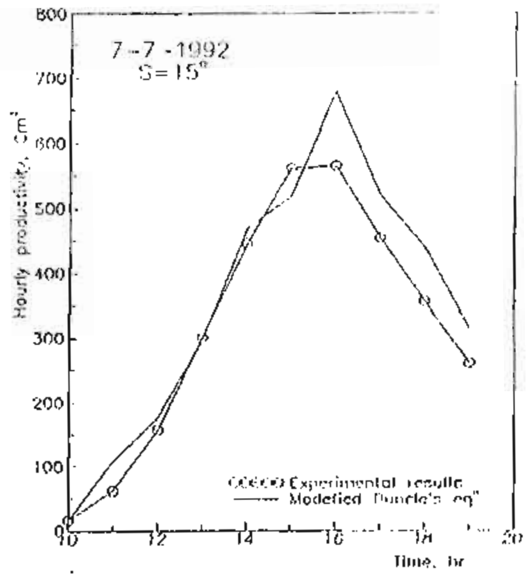

Fig. 6.b. Comparison between the measured and calculated results.

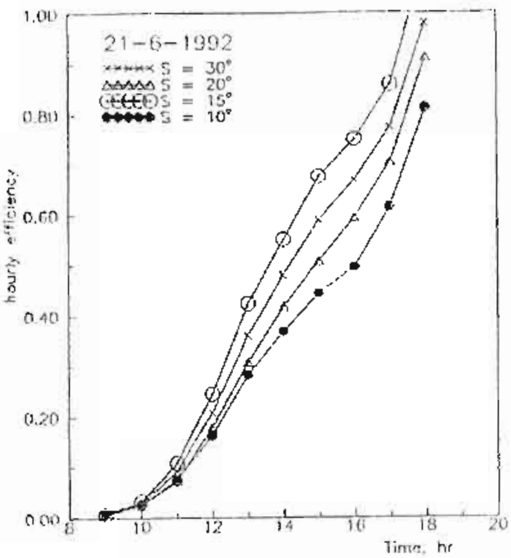

Fig 7.a. Variation of the hourly efficiency with time.

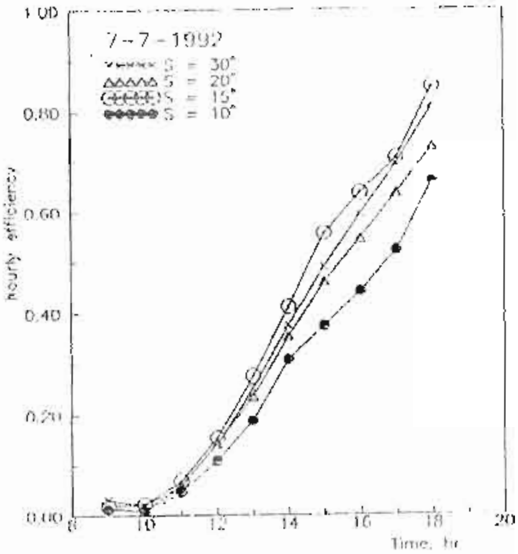

Fig. 7.b. Variation of the hourly efficiency with time.

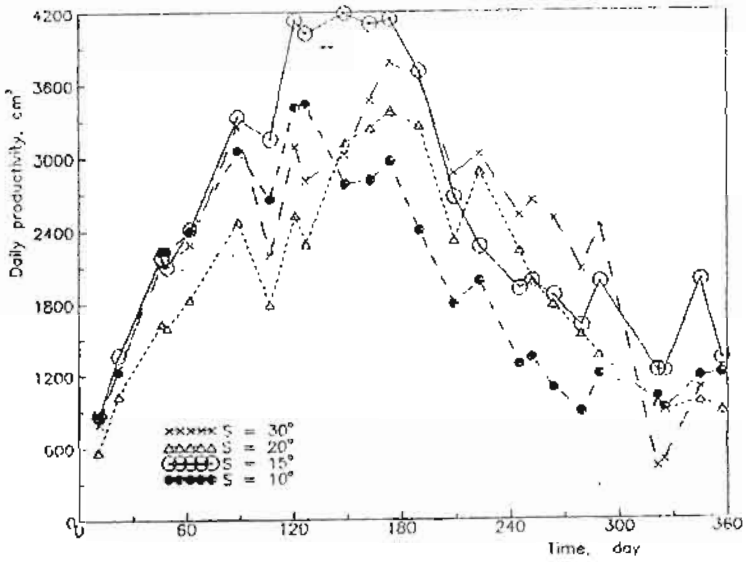

Fig. 8. Daily productivity of all stills over the year

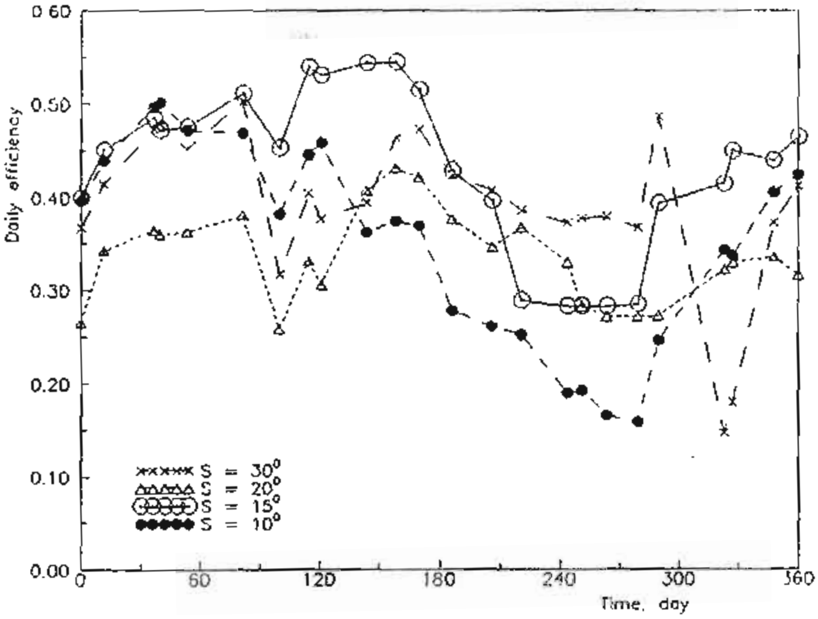

Fig. 9. Daily efficiency of all stills over the year.