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Performance of a F.R.P. pan evaporimeter

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ABSTRACT. Based on parallel evaporation measurements taken for 14 months on a standard U.S.A. class A pan evaporimeter and on an identically exposed and dimensioned pan made of Fibreglass Reinforced Plastic (F.R.P.) material, it is found that they do not compare well with each other in performance. Differences in their behaviour are explained in terms of the thermal properties of the pan. By virtue of the lack of heat exchange with the environment above ground as in the case of a standard U.S.A. class A pan and by the absence of advection interactions in ground as in the case of a sunken GGI-3000 pan, the fibreglass pan fared better in approaching values of evaporation from a giant sunken 20 m² tank of 2 m depth.

1. Introduction

Sunken pans have greater parity in aerodynamic and radiation characteristics with those of a lake, whose evaporation is a major demand for estimation from these pans. Also, advection of thermal energy from surroundings mainly occurring in the 1-2 m of depth from the ground surface, into the water body is largely taken care in sunken pans. On the other hand, tanks above ground are preferable in routine measurement for the simple reason of easy maintenance. Observations at Valday, U.S.S.R. showed that while sunken pan with 3000 cm^2 surface area deviates only by 4 per cent in evaporation from that measured in a sunken large tank with 20 square metre surface area, which can be assumed to equal any large shallow lake evaporation, standard U.S.A. pan deviates by as much as 52 per cent (WMO 1966). Riley (1966) writes the energy balance equation of the pan as :

$$G = R_n + L.E + A + (S+U)$$

where G is the total energy added to water, R_n is the net radiation, L is latent heat of evaporation and E is evaporation, A is the sensible heat, $(S+U)$ is the heat transferred through the side and the bottom. Cook (1968) observed the term $(S+U)$ exceeds $(L.E+A)$ throughout the period of bright sunshine. This is a factor which is not available to natural water bodies. In addition, thermal expansion of the tank material bring in some measurement errors (Krishnamurthy 1964). It is desirable to suppress these effects in pans. To some extent this is likely to be achieved by using a tank with material of inert thermal properties like F.R.P. in place of the copper tanks, standardly used. Fibreglass is a widely used material for its quality of corrosion resistance, insular properties and high strength to density ratio. Basically, it is a resin, reinforced with glassfibre. Its thermal properties vary widely depending upon the resin and the percentage of the glass used. But, the thermal constants of fibreglass, unlike copper approximate more closely to those of soil and water and, therefore, is more suitable as a material for both above-surface and sunken pans.

In the following, observations on a F.R.P. pan made during 1972 and 1973 at Pune are compared with parallel observations on standard U.S.A., GGI-sunken 3000 and 20 m^2 pan evaporimeters.

The pans were installed at the Central Agrimet. Observatory, Pune, located in the farms of Agricultural College. The exposure is good in all the directions except southward, where a single-storyed observatory building is located. However, the general wind direction is along east-west. The standard U.S.A., GGI-3000 and F.R.P. pans are exposed to the south of 20 m^2 tank so that the latter pans are not exposed to wind from over the 20 m^2 tank.

2. Analysis and discussion

(a) *Evaporation rates in Standard U.S.A. and F.R.P. pans*

Monthwise means of evaporation for each of the periods 0830 to 1430, 1430 to 1730 and 1730 to 0830 IST are computed. These values are given in Table 2. Monthwise, the differences in the hourly evaporation rates of Standard U.S.A. and fibreglass pans

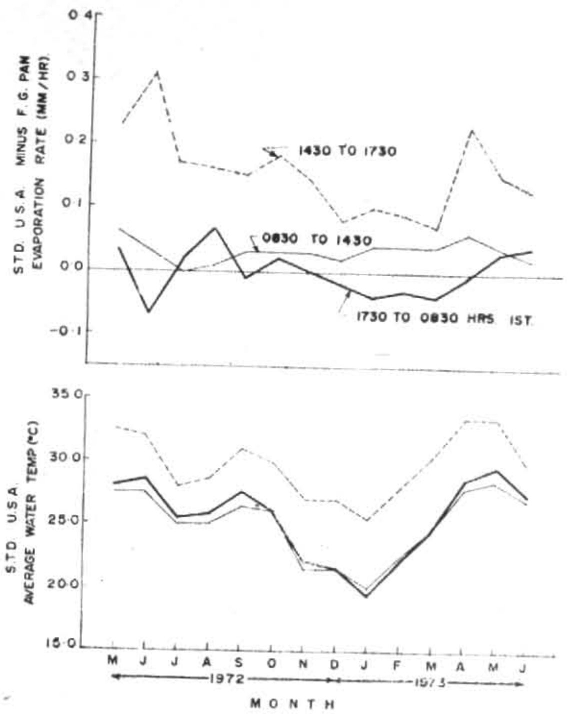

Fig. 1. Differences in the hourly evaporation rates of standard U.S.A. and F.R.P. pans during different periods of a day — Monthwise. Corresponding averages of standard U.S.A. water surface temperatures are also given.

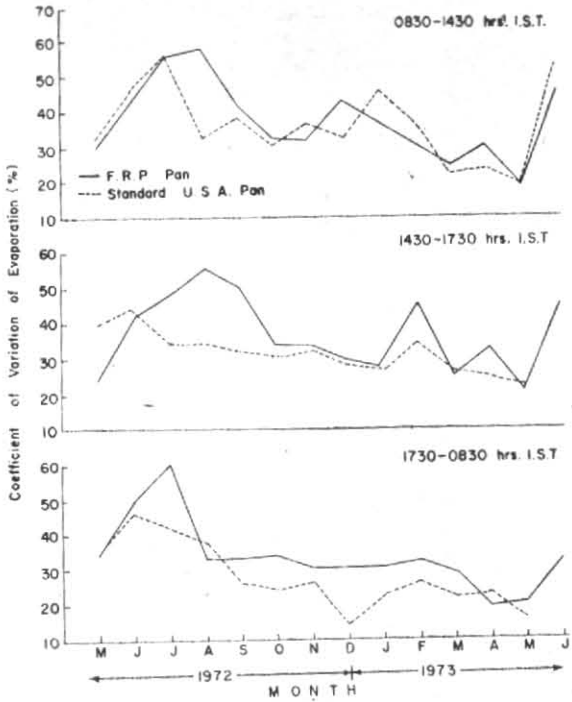

Fig. 2. Coefficients of variation of standard U.S.A. and F. R. P. pan evaporation during different periods of a day — Monthwise.

TABLE 1

Thermal characteristics at 20°C of F.R.P. and other materials of relevance

Material	Specific heat (cal/gm °C)	Thermal conductivity (kilocal/hr. m. °C)	Remarks
Fibreglass**	0·2-0·6	0·1-0·3	Depending upon the resin and the glass content used
Copper	0·09	335·0	—
Water	1·00	0·48	—
Soil*	0·2-0·5	0·36-0·95	*Depending upon moisture content (increasing with increasing moisture)

** *Handbook of Chemistry and Physics*, Ed. by C. Weast published by CRC Press (55th Ed.)

* *Soil Physics*—L.D. Baver; W.H. Gardner and W.R. Gardner; published by Wiley Eastern Ltd., New Delhi (4th Ed)

are presented in Fig. 1. Average of surface water temperatures for 0830 and 1430, 1430 and 1730 and 1730 and 0830 IST standard U.S.A. pan are also shown in the figure. Surface water temperature of F.R.P, was not recorded. The following are the interences from Fig. 1 :

(*i*) Among all the three periods of day, the difference in fibreglass and standard U.S.A. rates are large for the period 1430 to 1730 IST which is a period of high temperature during day. The differences in fibreglass and standard U.S.A. evaporation rates in all the months during the period 1730 to 0830 IST are not as high as during 1430 to 1730 IST, but standard U.S.A. pan evaporated slightly (about $<\cdot 1$ mm per hour) more than the fibreglass in all the months. This suggests a carry-over of heating during the 1430 to 1730 IST period into the 1730 to 0830 IST period, in class A pan.

(*ii*) During the 0830-1430 IST period the differences fluctuated on either side of zero suggesting that in this period water temperatures of both pans agree more with each other. Nevertheless, except during the month of June 1972, standard U.S.A. pan evaporated more in months other than of winter season. In winter season, the fibreglass pan evaporated more. In winter, it appears the F.R.P. pan still retains the heating, although less than that of standard U.S.A., to which it was exposed during the 1430 to 1730 IST period of the previous day. In other seasons, the heating of class A pan during 1430 to 1730 IST and its carry over to the other periods seems to be greater than in F.R.P. pan.

The negative difference in June 1972 for 0830 to 1430 IST period could not be explained. It is not known how far the larger errors in evaporation measurement during rainy season could have contributed to this.

(*iii*) It may be seen from the figure that the difference between the evaporation rates of the two pans varies from month to month, more or less, in step with the variation of the water temperature.

The larger difference between the two pans for the period 1430-1730 IST also corresponds to higher water temperatures of the period—illustrating that the differences between the two pans is due to their different thermal properties.

(b) *Coefficients of variation of evaporation from standard U.S.A. and F.R.P. pans*

From daily values, coefficients of variation (ratio of standard deviation to mean expressed as percentage) of evaporation for each month and for each of the three periods are presented in Fig. 2 for both the pans. The following are the inferences from Fig. 2 :

(*i*) Except during the month of August 1972, variability of evaporation during 0830 to 1430 IST from F.R.P. pan is generally of the same order as that of the standard U.S.A. (like the actual evaporation rates discussed above).

(*ii*) In the case of evaporation during 1430 to 1730 IST the coefficient of variation of F.R.P. is higher than that of the standard U.S.A. pan throughout (while actual evaporation is less). This higher variability of evaporation in F.R.P. pan can be due to lack of thermal exchange with environment through conduction which the standard U.S.A. pan maintains.

(*iii*) Coefficients of variation for the period 1730 to 0830 IST are high again for the F.R.P. pan compared to the standard U.S.A.

From the above it may be seen, either by the features of actual evaporation or its variability, maximum differences in the pans existed during the period around 1430 to 0830 IST.

(c) *Correlation between standard U.S.A. and F.R.P. pan evaporations*

Monthwise correlations for each period between the daily standard U.S.A. and F.R.P. pan evaporations are presented in Fig. 3. It may be seen that the variation of monthly correlation is less for the period 0830-1430 IST compared to the other two

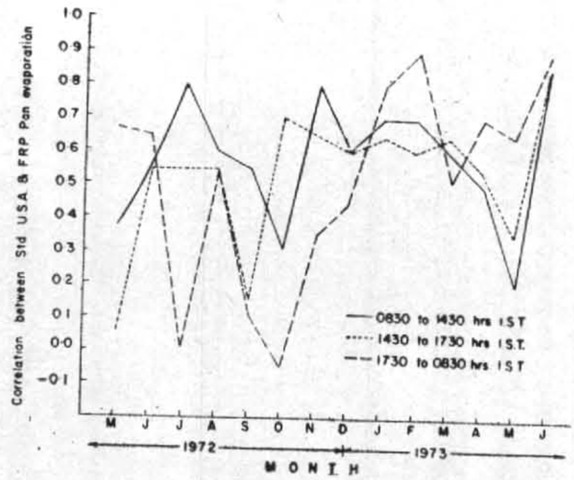

Fig. 3. Correlation between standard U.S.A. and F.R.P. pan evaporation during different periods of a day—Monthwise

Fig. 4. Percentage excess of evaporation in F.R.P., standard U.S.A. add GG I-3000 pans over that from 20m² tank — Monthwise (During 1973 April, observations on 20 m² tank were not taken as it was under repair).

periods. Generally, the correlations are relatively high for all the periods during winter and are of the same order. Average of the 14-monthly correlation values are 0·58, 0·53 and 0·51 for the periods 0830 to 1430, 1430 to 1730 and 1730 to 0830 IST respectively, although a few individual values exceeded 0·8. These low correlations indicate large differences in the response of each pan to a given environment.

(*d*) *Comparison of evaporation from F.R.P., standard U.S.A. and GGI-3000 with that from 20 m² tank*

Parallel observations of 24-hour evaporation (0830 to 0830 IST) on a large tank of 20 sq. metres surface area and on a small tank of 3000 sq. cm (GGI-3000 sunken pan), both embedded in soil, are also available. The effect of heat advection into any natural body of water is known to become

TABLE 2

Monthly means of daily evaporation (in millimetres)*

Time (IST)	Pan	1972 May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1973 Jan	Feb	Mar	Apr	May	Jun
0830-1430	Std. U.S.A.	3·3	3·0	1·7	2·1	1·9	2·7	2·0	1·5	1·3	1·9	2·4	3·3	4·0	2·7
	F.R.P.	3·1 (6)	3·4 (–12)	1·6 (6)	1·7 (23)	2·0 (–5)	2·6 (4)	2·0 (0)	1·6 (—6)	1·5 (—13)	2·1 (—5)	2·6 (—8)	3·4 (—3)	3·9 (3)	3·5 (8)
1430-1730	Std. U.S.A.	2·7	2·8	1·7	1·6	1·7	2·1	1·7	1·4	1·7	1·9	2·3	3·2	3·2	2·4
	R.F.P.	1·9 (42)	1·9 (47)	1·2 (42)	1·1 (45)	1·3 (31)	1·5 (40)	1·3 (31)	1·1 (27)	1·4 (21)	1·6 (19)	2·1 (10)	2·5 (28)	2·7 (18)	2·0 (20)
1730-0830	Std. U.S.A.	4·6	3·7	1·8	2·2	2·3	2·5	2·3	2·2	2·5	3·3	3·9	5·1	4·7	3·1
	F.R.P.	3·8 (21)	3·2 (16)	1·9 (—5)	2·1 (5)	1·8 (28)	2·0 (25)	1·8 (28)	1·9 (21)	1·9 (31)	2·6 (29)	3·3 (18)	4·1 (27)	4·0 (17)	2·3 (11)

*Percentage excess of evaporation of Std. U.S.A. pan over the F.R.P. pan is shown in brackets under F.R.P.

negligible as the size of the water body increases, while effects of heat storage would become of consequence. It is also known through earlier work (Venkiteshwaran *et al.* 1959) that there is no decrease in evaporation when pan diameter exceeds 5 m. Therefore, evaporation from 20 m^2 tank can be assumed to represent shallow lake evaporation. Evaporation measured from such tanks is practically equal to evaporation from shallow lakes or ponds (WMO Report 1969). In the following, the performance of each of the standard U.S.A., GGI and F.R.P. evaporimeters with respect to 20 m^2 tank is examined.

Monthwise percentage excesses of evaporation over 20 m^2 tank for each of the 3 evaporimeters, except for April 1973 when 20 m^2 tank was under repairs, are given in Fig. 4.

The following are the features of Fig. 4 :

(*i*) Throughout the observation period the F.R.P. pan evaporation is nearer to the 20 m^2 tank evaporation than the other two.

(*ii*) From the trend of the curves, it may be seen that evaporation from F.R.P. pan may also depart significantly from 20 m^2 tank in summer.

(*iii*) In monsoon period, during which 20 m^2 tank neither stores nor releases energy and is in radiative equilibrium, F.R.P. pan approaches very close to 20 m^2 values.

3. Conclusions

(*i*) F.R.P. pan behaves differently from the standard U.S.A. copper pan, although they are identically dimensioned and exposed. Mutual correlations are not high.

(*ii*) Differences between them are large during the period 1430 to 1730 IST. They are small during 0830 to 1430 IST.

(*iii*) Daily evaporation variability is higher with F.R.P. pan (In the light of the comparison of F.R.P. pan and 20 m^2 tank evaporation values at Fig. 3, one may conjecture variation in daily lake evaporation also may be higher than what is shown by standard U.S.A. pan).

(*iv*) F.R.P. pan approached the 20 m^2 tank more closely than the other two pans discussed.

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