ENERGY BALANCE CONSIDERATIONS IN THE DESIGN OF FLOATING COVERS FOR EVAPORATION SUPPRESSION

by

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I hereby recommend that this dissertation prepared under my direction by Keith Roy Cooley

entitled Energy Balance Considerations in the Design of Floating Covers for Evaporation Suppression

be accepted as fulfilling the dissertation requirement of the degree of Doctor of Philosophy

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ABSTRACT

This study consists of a theoretical analysis of the energy balance equation for a partially covered body of water, and experimental analyses of the energy balances of partially covered insulated evaporation tanks.

The theoretical analysis indicates that surface reflectance for solar radiation and infrared emittance are the most important cover properties. White colored materials were found to satisfy the requirement that both these parameters be as large as possible.

Experiments were conducted using covers of foamed wax, lightweight concrete, white butyl rubber, and styrofoam. A variety of shapes and sizes were tested. Cover radiative properties were again noted to be most important, and thin covers proved to be slightly more efficient than thick insulated covers of the same size.

Evaporation reduction was found to be proportional to the percent of surface area covered, the constant of proportionality depending upon the color and type of material used. For the white, impermeable materials tested, the constant of proportionality was near unity. It was also noted that reduction in evaporation and reduction in net radiation, as compared to an open tank, were highly correlated.

Evaluation of two Dalton-type expressions, the Bowen ratio method and the combination method, for predicting evaporation from

an open water surface, showed the combination method to be better under conditions of this experiment. Based on this finding, a modified combination method was derived. This modified equation proved valid for predicting evaporation from a partially covered body of water.

The use of insulated evaporation tanks also provided an easy and accurate method of predicting net radiation over other surfaces, and long-wave atmospheric radiation.

INTRODUCTION

Hydrologists and engineers have long been aware of the tremendous quantity of pure water lost each year through the process of evaporation. Meyers (1962) has estimated this loss to be over 17,000,000 acre feet per year from lakes, reservoirs, and ponds in the 17 western states alone. This amounts to considerably more than the average annual flow of the Colorado River as measured at Lee's Ferry, which is less than 13,000,000 acre feet per year (U.S.G.S., 1964).

Because of the potential savings ($170,000,000 per year at an average cost of $10 per acre foot), many studies have been conducted on methods to reduce evaporation. By far the greater number of these have been concerned with the application and utility of various combinations of mono-molecular layers or films of long-chain alcohols. In attestation of this fact are two recent bibliographies on evaporation reduction (Reidhead, 1960; Magin and Randall, 1960), each containing over 300 references devoted almost exclusively to either the use of monolayers or the general process of evaporation. In fact, only one reference specifically mentions the use of other means to reduce evaporation in its title. Another example is the proceedings of a recent conference on evaporation reduction (Larson, 1963), in which only one short paragraph mentions the use of floating materials other than monolayers.

Since most of the above-mentioned studies have been somewhat discouraging, with savings of only 10-35 percent realized on field tests (Cruse and Harbeck, 1960; Cluff, 1966), it was decided that another approach to the problem should be investigated. In particular, the present study was initiated to determine the physical properties that should be considered in the design of floating covers used to reduce evaporation from water surfaces, and to obtain a better understanding of the evaporation process from a partially covered body of water. It consists, first, of a theoretical analysis of the energy relations of a partially covered body of water, and, second, of controlled experiments on partially covered insulated evaporation tanks. Only floating materials covering less than 100% of the surface area are considered; and a combination aerodynamic-energy balance equation is derived to predict evaporation from these partially covered surfaces.

REVIEW OF LITERATURE

An investigation of the literature related to evaporation reduction indicates that nearly all of the studies conducted to date have been of an experimental nature; that is, a material was placed on or above the water surface, and observations of its effectiveness recorded. The material most commonly used has been a monomolecular layer of some long-chain or fatty alcohol which would float on the water surface. In some cases very detailed studies were conducted; and complete research teams investigated the effects of various parameters (monolayer and meteorological) on evaporation. During these investigations it was determined that the monolayers had little or no effect on the reflectance or emittance of the water surface (Harbeck and Koberg, 1959). Therefore, since one of the purposes of this study is to determine the effects of cover properties (the reflectance and emittance of which are considered to be very important) on the energy balance and evaporation, studies relating exclusively to the use of monomolecular layers will not be discussed in this review. Rather, this space will be devoted to those papers that investigate or mention the use of reflective materials or application of other methods to change the reflective properties of the water surface.

Although it was noted by Young (1947) that the rate of water loss from an evaporation pan was affected by the pan's color, the first reference to indicate that the color of the water affected evaporation was that of Bloch and Weiss (1959). They noted an apparent reduction in evaporation and water temperature when the Dead Sea turned milky white due to carbonate of lime being dispersed through the surface. This prompted them to study the effect on evaporation of white polyethylene balls placed on the water surface of small pots. These balls, which were about 90 percent submerged, reduced evaporation approximately 40 percent, whereas black balls of the same type and number had no significant effect on the amount of evaporation as compared to an open pot. They attributed the reduction, in both the case of the Dead Sea brine and the white balls, to the reflective properties of the white material.

Another example indicating that the color of the water has an important effect on evaporation was presented by Keys and Gunaji (1967), in which they showed an increase of evaporation using a blue dye, but no significant difference when a red dye was used.

Genet and Rohmer (1961) performed studies using beakers of 1 liter capacity on which they placed layers of various thickness of white polystyrol beads. One series of studies was conducted in an oven where only the temperature affected the results. A later study consisted of placing the beakers outdoors; and for the same temperature as that in the oven, the efficiency increased because the white beads reflected a portion of the incoming radiation. An increase in thickness of the layer of beads only slightly improved the efficiency. This experiment lasted approximately 1 month, and data indicated an average evaporation reduction of 56 to 64 percent. The authors noted that since this study was conducted using small beakers, the results may not have been representative of what would happen on larger bodies of water.

Crow and Manges (1965) also reported on the use of white floating spheres as well as wind baffles, plastic mesh, and two other materials, to reduce evaporation. The wind baffles were simply to reduce the turbulent air motions over the ponds. The plastic mesh materials were said to have reduced incoming radiation to the water by shading, as well as reducing wind speed, since they were suspended above the surface. The white floating spheres were noted to be more efficient than any of the other methods, but no mention was made of the process by which they were able to reduce evaporation so efficiently. The data reported were insufficient to allow the reader to make any meaningful conclusions since the length of the study, dates of observation, and meteorological conditions were not reported. These tests were conducted under field conditions on plastic lined ponds of 30.5 x 36.6 x 1.8 meters (100 x 120 x 6 feet) in size.

Another study conducted under field conditions on 500 m^2 ponds was reported by Rojitsky and Kraus (1966). They tested a variety of floating materials. However, most failed due to sinking and deterioration; and no results were reported other than some visual observations. In another study they placed several different floating materials, including a variety of aquatic vegetation called Lemna (duckweed), on Class A pans and observed evaporation, temperature of the top centimeter of water, and wind speed. This study lasted for a period of eight months for some materials. Evaporation reduction of up to 82 percent was noted with a white polyethylene powder which covered essentially 100 percent of the water surface, and with the vegetation "Lemna" which also covered the entire surface. The vegetative cover also maintained the water temperature at the lowest average for the study period. Hexadecanol reduced evaporation 66 percent during this period, and the surface temperature was the highest of any recorded.

Cluff (1967) reported on the use of several different types of floating rafts to reduce evaporation. These rafts were constructed of 4-mil polyethylene plastic sheets, aluminum foil bonded to styrofoam, butyl rubber, lightweight concrete, and styrofoam sheets painted white. He indicated the most promising appeared to be the styrofoam painted white and the aluminum foil bonded to styrofoam because they are stronger and reflect more energy than some of the other materials. No data were included to substantiate these conclusions, however.

An experiment by Yu and Brutsaert (1967) using very shallow evaporation pans of various sizes showed the effect of reflective properties. Eight pans about 2.5 cm deep and built in three sizes of .3 meters (1-foot) square, 1.2 meters (4-foot) square and 2.4 meters (8-foot) square were used. There were white and black pans of each size, and also a green and grey pan in the 1.2 meter (4-foot) size. The albedo of each color of pan with about 16 millimeters (5/8-inch) of water was determined in the laboratory under simulated clear sky and zenith sun conditions. These values were reported as an average for weighted wave lengths of the visible spectrum. The values obtained were: white - 0.675, black - 0.054, green - 0.09, and grey - 0.108. Meteorological data as well as water temperature and evaporation were recorded during the series of runs which lasted about 3 hours each.

Results of the experiment showed that the highest rate of evaporation generally occurred on the 2.4 meter (8-foot) black pan while the lowest was on the 2.4 meter (8-foot) white pan. For the three black pans, evaporation generally increased with size while the opposite was true for the white pans.

A plot of $E/(e_s - e_a)$ vs U for the pans indicated that the coefficients a and b, from the equation

$$E = a + bU(e_s - e_a) \qquad [1]$$

were the same for the same size pan regardless of the color. In this equation, E is the evaporation, e_s and e_a the vapor pressure at the surface and in the air above, respectively, and U the windspeed at the place e_a is measured. Since the color of the pan did not alter the coefficients, the turbulence of the air above the pans must not have been changed significantly either.

A correlation was also noted between the difference in evaporation between the white and black pans, and the incoming radiation.

Another study on evaporation from shallow water was reported by Fritschen and Van Bavel (1962 and 1963c). They presented a complete heat balance on an hourly basis from a shallow pond of water. Their interest was in determining the effect of the surrounding medium on evaporation. Thus, they did not report values of the albedo of shallow water over a black plastic which they used.

Only one paper was found in which an attempt was made to determine what effect various covers could have on evaporation due to their reflective properties (Bromley, 1963). In this paper the author noted that much of the heat absorbed by a water surface comes from incident solar radiation. The surface water temperature, and thus evaporation, could therefore be reduced by preventing part of the solar radiation from entering the water. Some of the methods he proposed to accomplish this are:

1 - Produce a smoke or cloud layer above the lake surface, or otherwise produce a shadow. (This is similar to the method explained by Crow and Manges in which they suspended a plastic mesh above the surface.)

2 - Float a thin layer of suitable solid on the surface, e.g. flakes, bubbles, powders, beads, etc.

3 - Float a thin layer of suitable foam on the surface.

4 - Float a solid sheet on the surface to act both as a diffusion barrier and a radiation reflector.

Although all of these methods should be effective, attention is confined to the surface coatings. In order to evaluate the effectiveness of these coatings, he used the energy equation for an open body of water. This equation, considering no change in energy stored within the water, can be written in present notation as:

$$(1-r_w)S + (1-r_w')Ra - \varepsilon_w \sigma T_w^4 + K_A(T_a - T_w) - LK_E(e_s - e_a) = 0 \qquad [2]$$

where

r_w = reflectance of water surface to solar radiation

r_w' = reflectance of water surface to atmospheric radiation

S = solar radiation

Ra = atmospheric radiation

ε_w = emittance of water surface

σ = Stefan-Boltzmann constant

T_w = temperature of water surface

T_a = temperature of air

K_A = heat transfer coefficient

K_E = mass transfer coefficient

L = latent heat of vaporization

e_s = saturated vapor pressure at surface water temperature

e_a = actual vapor pressure of air.

By assuming a set of values for meteorological variables typical of those observed during summer weather in the southwestern

United States, and using values of K_A and K_E based on previous studies, the surface temperature was calculated. Once the surface temperature was known, evaporation was calculated using the last term in the energy equation.

Bromley used the same equation when surface coatings were considered, except additional assumptions were necessary. First it was assumed that the heat transfer coefficient did not change, and second, that the mass transfer coefficient could be defined as:

$$1/K_E = 1/K_w + 1/K_c \qquad [3]$$

where $1/K_w$ and $1/K_c$ refer to the resistance to evaporation of the air and cover, respectively. The surface temperature and evaporation were again calculated, and the effectiveness of the coating determined by comparing the two values of evaporation calculated. These comparisons were made assuming that the following surface treatment materials were available to be applied singly or in combination:

1 - monolayer (1 sec/cm resistance)

2 - monolayer (4 sec/cm resistance)

3 - white material $r_c = 0.8$, $\varepsilon_c = 0.8$

4 - metallic material $r_c = 0.9$, $\varepsilon_c = 0.1$

5 - impervious coatings.

Results of the calculations of evaporation, comparing treated and untreated surfaces, were presented for three possible situations. The first considered effectiveness of the coatings after steady state conditions were reached (in this case a 30-day period). The second considered the amount of water lost to evaporation (in the first three days) if the coating was suddenly removed after steady state had been reached. The third situation considered the effectiveness of the coatings for both a short time coverage, and total savings for a longer period where the coating was only in place for a short time.

The general trend of all his calculations indicated that the best coatings in descending order were: 100 percent impervious white layer, monolayer (4 sec/cm) plus white surface, 100 percent white or metallic surface, 100 percent monolayer (4 sec/cm), 50 percent white or metallic surface, and 100 percent monolayer (1 sec/cm). The percent of water saved ranged from 100 to 17 percent for the above coatings.

Bromley (1963) also conducted two experimental studies using small plastic or rubber trays approximately 25 mm x 30 mm x 5 mm (10-inch x 12-inch x 2-inch) deep. Coatings used during the first experiment consisted of white diatomaceous earth treated with water rep-pellent, and a monolayer of 90 percent cetyl alcohol. Both covers reduced evaporation by essentially the same amount, averaging 23 percent, and both showed signs of deterioration after only two days. During the second experiment coatings of expanded polystyrene beads of various densities and sizes were placed on the water surface. The savings varied from 41 to 59 percent with the lightest beads producing the best results. This experiment also lasted for only a couple of days.

Comparison of experimental results with calculated values is difficult since the calculated values were determined considering different surface treatments. Although experiments were conducted on very small pans and for short time intervals, and calculations are not verified, both indicate considerable savings can be achieved using reflective coatings.

THEORETICAL CONSIDERATIONS

An equation basic to most of the engineering, hydrological, and meteorological disciplines is the energy balance or conservation of energy equation. In evaporation studies, this equation, relating the balance between the inflow and outflow of energy in a unit volume of water, is usually written as:

$$Rn = LE + G + A \qquad [4]$$

(Sellers, 1964), where

LE = rate of energy used in the evaporation process (latent heat transfer)

Rn = rate of net radiation reception by the water surface

A = rate of sensible heat transfer from the surface to the air

G = rate of sensible heat transfer from the surface to deeper layers of water or change in energy stored in the water

and all terms are expressed in units of cal cm^{-2} min^{-1}.

If the energy balance equation is considered for a time period such that the change in storage is equal to zero (which may be a 24-hour period, a season, or any other time interval at the extremities of which the amount of energy stored in the water is the same), the storage term can be ignored and the equation [4] written as

$$LE = Rn - A \quad . \tag{5}$$

Since the objective of evaporation reduction is to minimize LE, it is obvious that to do this the combination of Rn - A must also be minimized; and in order to do this, it is necessary to know the individual constituents of each of these terms and the relationships existing among them. In the case of a partially covered body of water, the net radiation may be written as follows:

$$Rn = Ra + S - [(1-p)r_w + pr_c]S - \sigma[(1-p)\varepsilon_w T_w^4 + p\varepsilon_c T_c^4] - [(1-p)r_w' + pr_c']Ra \tag{6}$$

where

p = percent of surface area covered expressed as a decimal

r_c = albedo of cover

ε_c = emittance of cover

T_c = temperature of cover surface

r_c' = albedo of cover to long-wave radiation

and the other terms are as previously defined.

The term $(1-p)r_w'$ Ra is generally an order of magnitude or more smaller than the other terms and is therefore neglected, being usually less than the errors associated with measurements of the other parameters.

The equation for sensible heat transfer is commonly written (Conaway and Van Bavel, 1966) as:

$$A = \frac{\rho\, c_p\, k^2\, U\, (T_s - T_a)}{[\ell n\, (z/z_o)]^2} \qquad [7]$$

in which

ρ = density of air

c_p = specific heat of air at constant pressure

k = Von Karman constant

U = wind speed at elevation z

T_s = temperature of surface $[T_s = (1-p)\, T_w + pT_c]$

z = height above surface at which U and T_a are measured

z_o = roughness parameter of surface

Sensible heat transfer from the air to the surface is defined as positive for this equation.

Combining equations [6] and [7] yields a working equation with which to investigate possible ways of minimizing the total evaporation:

$$Rn - A = Ra + S - [(1-p)r_w + pr_c]S - \sigma[(1-p)\varepsilon_w T_w^4 + p\varepsilon_c T_c^4] - pr_c^{'} Ra$$

$$- \frac{\rho\, c_p\, k^2\, U\, (T_s - T_a)}{[\ell n(z/z_o)]^2} \quad . \qquad [8]$$

Floating covers placed on a water surface will not affect such items as Ra, S, r_w, σ, ε_w, ρ, c_p, k^2 and z. Also, once the size of cover has been selected the percent of area covered will be constant. U and T_a should not be changed by the cover either, since they represent the general conditions within the air mass. Dependent items such as T_w, T_c and T_s, will be affected by the cover, however, they cannot be determined prior to application. The remaining items, r_c, ε_c, $r_c^{'}$, and z_o are the independent variables that can be manipulated by the design of the cover and the material used. Since r_c, $r_c^{'}$, and ε_c appear in negative terms, the larger they are made the smaller the sum of all terms will be. The roughness parameter, z_o, is also a part of a negative term, and it would appear desirable to make this factor as large as possible by creating a very rough surface. However, if T_a is larger than T_s on the average, the sensible heat term will be positive and increase energy available for evaporation. Therefore, in this case, a small value of z_o would be desirable. One other observation concerning the sensible heat term can be made; if a very thin material is used for the cover, the temperature of the cover will be essentially the same as the temperature of the water. Since the temperature of the air cools faster than the temperature of the water after sunset, energy will be transferred from the water to the air, through the cover, during the early evening hours, thus reducing the energy available for evaporation. During the early morning hours the opposite would be true. The time of day of maximum wind activity may therefore determine if rough but relatively thin covers would be desirable.

Another way to approach the problem of minimizing the net radiation term, and to get a better feel for the values of r_c', r_c, and ε_c to design for, is to consider a surface capable of exchanging heat only by radiation. This surface would receive long-wave radiation from the sky (Ra), of which it would absorb a fraction ε (emittance = absorptance = 1 - reflectance, for an opaque material and long-wave radiation). It would also receive short-wave radiation from the sun and sky (S) of which it would absorb a fraction α. Emittance of radiation by the surface would be determined by its temperature and emissivity, and the energy balance equation for such a surface would then be:

$$\varepsilon\sigma \, T_s^{\,4} = \alpha S + \varepsilon Ra \quad . \qquad [9]$$

Since the lowest evaporation would be associated with the lowest temperature at the surface, the above relationship is expressed in terms of the temperature as

$$T_s = [\frac{\alpha}{\varepsilon}(\frac{S}{\sigma}) + \frac{Ra}{\sigma}]^{1/4} \quad . \qquad [10]$$

Knowing S is zero at night, it can be seen that at night the surface temperature is independent of α and ε, and depends only on Ra and σ, neither of which will be altered by a cover. During the daytime, since again Ra, σ, and S will not be altered by the cover, the lowest ratio of α/ε will produce the lowest surface temperature.

Moving one step closed to reality, we know that in fact the surface temperature is not independent of energy emitted at night, due to the fact that it is thermally coupled to the water or heat reservoir. The water reservoir maintains a fairly stable temperature because of its heat capacity properties. Since the true surface temperature of the water is always greater than the radiative temperature of the atmosphere, the argument for a high emittance being desirable is strengthened, even for nighttime periods. This is true since, although a greater percent of energy will be absorbed due to the higher emittance, the same percentage of a larger term will be emitted.

Using the published values for the absorptivity and emissivity of several materials (Brown and Marco, 1958), the ratio of α/ε is presented in Table 1 below. As shown there, the lowest ratio of absorptivity to emittance (which is another way of saying high reflectivity and high emittance) is obtained from white materials. Thus, other factors such as roughness, permeability, and thickness being equal, white materials will be more efficient in reducing evaporation than the others listed.

Although results of this study cannot be compared directly with those obtained by Bromley, his calculations also indicate that white colored materials are the most efficient in reducing evaporation.

Table 1

Ratio of absorptivity and emissivity for various materials

Material	$\alpha = 1 - r$	ϵ	α/ϵ
White paint	0.12 - 0.26	0.80 - 0.95	0.13 - 0.33
Avg.	0.19	0.88	0.22
White paper	0.27	0.92 - 0.95	0.28 - 0.29
Avg.	0.27	0.93	0.29
Roofing paper	0.88	0.91	0.97
Black paint	0.97 - 0.99	0.96 - 0.98	0.99 - 1.03
Avg.	0.98	0.97	1.01
Polished aluminum	0.26	0.04	6.5
Polished copper	0.26	0.02 - 0.03	8.7 - 13.0
Avg	0.26	0.025	11.0

EXPERIMENTAL FACILITIES & SYSTEM EVALUATION

Experimental Site. The experimental studies were conducted during the summers of 1967 and 1968 on four evaporation tanks located at the U. S. Water Conservation Laboratory near Phoenix, Arizona, in the Salt River Valley. The Salt River Valley slopes gently to the west and is ringed by mountains rising 300 to 900 meters above the valley floor. In the vicinity of the Laboratory, the nearest obstruction to wind is a 360 meter high mountain located about 4 kilometers south of the site. The Laboratory grounds are surrounded by the University of Arizona Cotton Research Center. Farm lands immediately adjacent to the evaporation tank site are planted to a variety of crops. The western exposure is dominated by Laboratory buildings, the nearest of which is located 18.3 meters (60 feet) west of the western-most tank. A plan view of the evaporation tanks and Laboratory buildings is shown in Figure 1.

Evaporation Tanks and Covers. The evaporation tanks consisted of an outer tank 2.7 meters in diameter and 0.9 meters deep, and an inner tank 2.1 meters in diameter and 0.6 meters deep. The smaller tank was placed inside the larger with the top rims in the same plane. Perlite ore was placed on the bottom and sides between the two tanks. The tanks were buried with the rims protruding slightly above ground level. The use of insulated tanks more nearly simulates pond or lake conditions (Riley, 1966), and also simplifies the energy balance

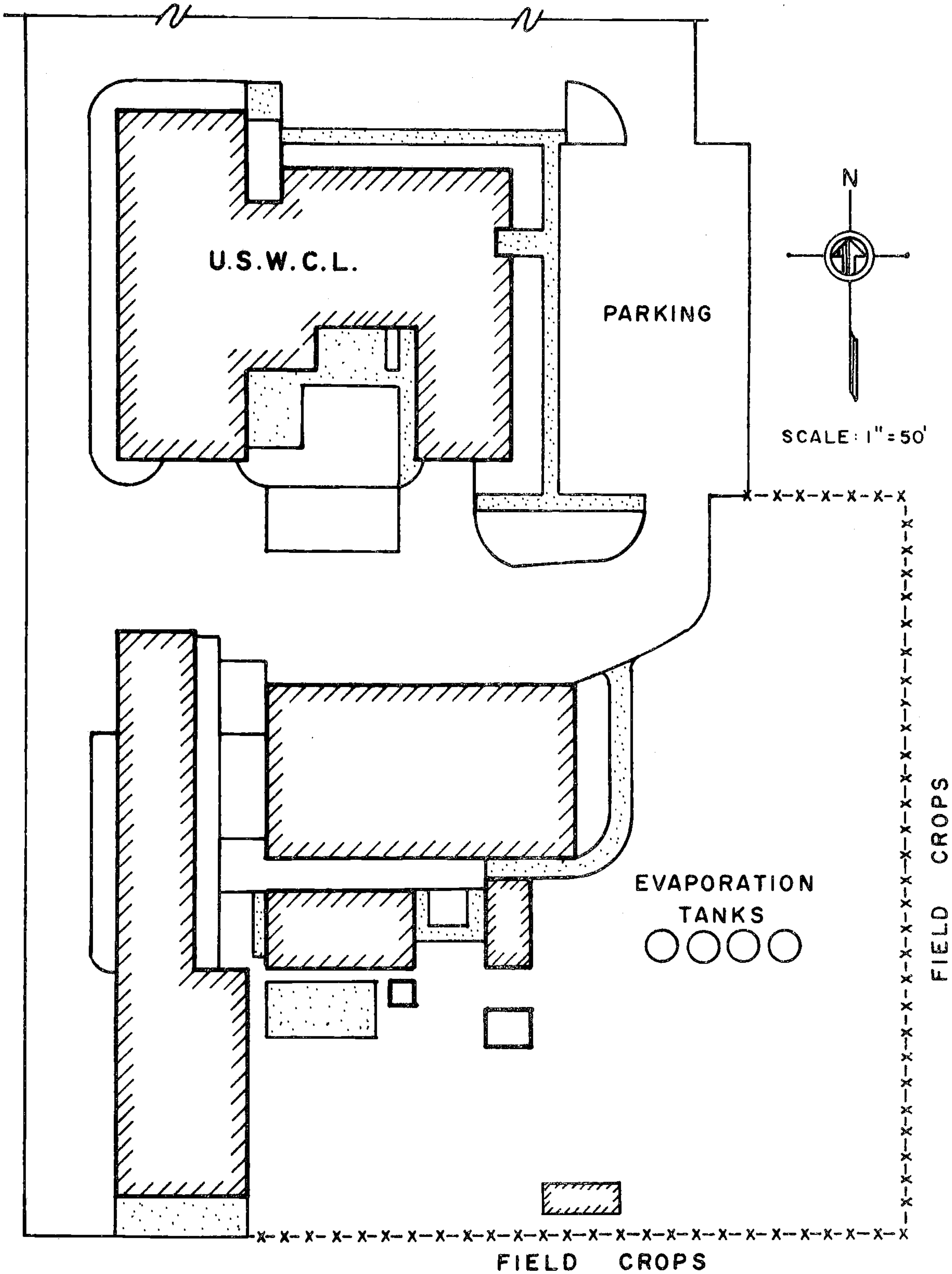

Figure 1.--Plan view of evaporation tanks and surroundings.

equation. Covers were placed on three of the tanks and the fourth was used as a standard throughout the experiment.

Four covers of two different types, individual floating blocks and single membranes or sheets, were studied. The block materials used were: white foamed wax formed into blocks about 12 cm in diameter by 4 cm thick; and lightweight concrete formed into blocks about 18 cm x 28 cm x 4 cm of light grey color. The membrane or sheet materials were: butyl rubber of 15 mil thickness painted white on top; and 5 cm thick styrofoam also painted white to establish a similar reflective surface as the butyl rubber. The rubber membrane was floated by means of a sealed plastic pipe attached around its perimeter.

During the summer of 1967 all four of the materials were used. The percentage of surface area covered by the four materials was essentially the same. Both the wax, and concrete, blocks covered 78 percent, the styrofoam covered 80 percent, and the butyl rubber covered 86 percent, of the surface area of a tank.

During 1968 only styrofoam and butyl rubber materials were used. Six covers were constructed to give different surface area coverages on the tanks. All six of the covers were round. One cover had a large hole (95 cm in diameter) in the center. Another cover had 12 small holes (27 cm in diameter) spaced symmetrically about the center. Each of these, referred to as 1-hole and 12-hole, covered 76 percent of the surface area. The percentage of area covered by the other four varied from 26 to 87 percent.

Evaluation of Measurements and Measuring Devices. The meteorological, heat flow, and evaporation data necessary to determine a complete heat budget on each of the four insulated evaporation tanks were measured. This consisted of the following measurements for each tank: water surface temperature, water temperature 10 cm below the surface, water temperature at the bottom, net radiation, reflected solar radiation, and cover surface temperature. Also recorded near the tanks and 0.9 meters above the ground surface were: solar radiation, dew point temperature, air temperature and wind speed and direction. All of the temperatures were obtained using thermocouples. The surface temperature of the water was determined by floating a shaded thermocouple on the water surface (Jarvis and Kagarise, 1961).

Heat stored in the water was computed from the hourly average tank temperature which was derived from the temperature profile data. Net radiation was measured using Fritschen miniature net radiometers (Fritschen, 1963, 1965a), placed 23 cm above the tanks and 76 cm from the rim.

The sensible heat transfer to or from the tank was determined as a residual in the energy balance equation. However, the necessary data to calculate sensible heat transfer by means of a Dalton-type expression which relates sensible heat transfer with meteorological parameters were available. The energy used in evaporation was determined from water level measurements, and the heat stored in the cover was determined from temperature measurements on top and bottom of the cover.

During 1967 all of the above measurements, except evaporation or water level, were recorded every 30 minutes during the study periods by means of a data handling system capable of recording, on punched tape, the output of 49 channels of data. (For more detail see Fritschen and Van Bavel, 1963a.)

The water level during 1967 was continuously recorded by means of Stevens Type F water stage recorders with a magnification of two times. Although the original plan was to calculate the heat balance on an hourly basis, it was impossible to obtain sufficiently accurate hourly evaporation measurements from the water stage charts. The minimum time period that could be used to obtain the desired precision of measurement was 12 hours on the open tank and 24 hours on the covered tanks. It was therefore necessary to use evaporation equations to compute hourly evaporation values from meteorological data. These computed hourly evaporation values were then summed for either 12 or 24 hours, depending on the tank under consideration, and the total compared to the measured value as read from the water stage chart. If the two totals were essentially the same, the computed hourly values were considered representative of actual evaporation and used in the heat balance calculations.

In 1968 the water stage recorders were replaced by capacitance proximity sensing probes, manufactured by Drexelbrook Engineering Company. These probes compare the capacitance between the sensing plate and the water surface with a reference capacitor in the control unit. Variations in the water level changes the variable capacitance and produces a corresponding change in the output current. Precision of these units is better than 1/2 percent of full scale, which in these studies was less than 16 millimeters. Since the output from these units was an electrical signal, they were connected to the data handling system and all data were recorded every 30 minutes on punched tape.

Comparison of evaporation measurements made by a standard point gage, and the capacitance probes, are presented in Table 2. These data show that the two methods give essentially the same results. The difference is generally within the possible error of $\pm$ 0.01 cm which applies to both methods of measurement. The worst conditions were obtained on Tank #4 for the period of 13 to 16 August where a difference of 0.13 cm is noted. This may have been due to a bad point gage reading or an erroneous output from the probe caused by dirt or grass on the capacitance plate. It is felt that these measurements are sufficiently close to allow use of the capacitance probe for all evaporation measurements.

The evaporation tanks are shown in Figure 2. This figure shows the location of the tanks with respect to the nearest buildings, the

Table 2

Comparison of Capacitance Probe Data and Pointgage Readings (cm)

Date	Tank #1			Tank 2			Tank 3			Tank 4		
	Pointgage	Probe	Diff	Pointgage	Probe	Diff	Pointgage	Probe	Diff	Pointgage	Probe	Diff
31 JUL 0830												
1 AUG 1000	.15	.16	.01	.59	.60	.01	.25	.15	.10			
2 AUG 0800	.09	.11	.02	.81	.83	.02	.15	.17	.02			
2 AUG 1530	.04	.03	.01	.25	.25	-	.04	.08	.04			
3 AUG 1630	.08	.09	.01	.74	.78	.04	.13	.17	.04			
Total	.36	.39	.03	2.39	2.46	.07	.57	.57	-			
13 AUG 0930												
14 AUG 0800	.10	.11	.01	.78	.79	.01	.42	.46	.04	.62	.68	.06
15 AUG 0800	.19	.16	.03	.89	.88	.01	.47	.51	.04	.62	.73	.11
16 AUG 0800	.12	.12	-	.65	.64	.01	.37	.34	.03	.58	.54	.04
Total	.41	.39	.02	2.32	2.31	.01	1.26	1.31	.05	1.82	1.95	.13
20 AUG 1600												
22 AUG 0800	.18	.18	-	.90	.85	.05	.25	.22	.03	.31	.28	.03
23 AUG 0800	.15	.14	.01	.79	.81	.02	.23	.21	.02	.27	.27	-
24 AUG 1000	.11	.13	.02	.63	.65	.02	.15	.17	.02	.20	.21	.01
Total	.44	.45	.01	2.32	2.31	.01	.63	.60	.03	.78	.76	.02

Figure 2. Layout of evaporation tanks and instruments.

covers and instruments on the tanks, and the general appearance of a typical experimental run. The trailer in the upper left-hand portion of the figure is a mobile meteorological laboratory and contains the recording system and power supply used.

Calibration of Insulated Tanks. Calibration of the insulated evaporation tanks consisted of determining how well evaporation compared on the four tanks without covers. Previous investigators had noted no difference on the 2.7 meter diameter tanks as long as the water level was within 13 cm of the rim (Frasier and Myers, 1968). In June and July of 1968 the tanks were again calibrated to determine if the modification had affected the evaporation. Results of point gage measurements are presented in Table 3. Values of net radiation for portions of the calibration period are also presented. These measurements show that evaporation between the individual tanks varied by less than 2 percent for the entire period, and less than 2 percent for individual days. Net radiation varied by almost 6 percent for individual days, but only slightly over 3 percent for the total period. These values compare favorably with those obtained earlier, and indicate that evaporation can be considered the same for all tanks.

Evaluation of Insulation. Evaluation of the insulation was accomplished by comparing temperature measurements at several points inside and outside the tanks for 24-hour periods. Thermocouples were placed on the center of the bottom and halfway down the sides (at the

Table 3

Calibration of Evaporation Tanks

Evaporation in cm, Net radiation in ly

Period	Tank #1 E	Tank #1 Rn	Tank #2 E	Tank #2 Rn	Tank #3 E	Tank #3 Rn	Tank #4 E	Tank #4 Rn
26 JUN 0800– 27 JUN 0800	.88	466	.88	483	.87	475	.90	469
27 JUN 0800– 28 JUN 0800	.93	431	.94	455	.92	458	.95	442
28 JUN 0800– 1 JUL 0800	2.61	-	2.58	-	2.59	-	2.65	-
*1 JUL 1600– 2 JUL 1600	.80	-	.81	-	.81	-	.82	-
2 JUL 1600– 3 JUL 1600	.90	517	.91	511	.93	524	.92	528
3 JUL 1600– 4 JUL 1600	.89	513	.88	514	.89	538	.89	530
Total	7.01	1927	7.00	1963	7.01	1995	7.13	1969

* Tanks were refilled on 1 JUL 0800.

four compass points) of the outer tank. Temperatures at the center of the inner tank were recorded at the surface, at 10 cm below the surface, at 38 cm below the surface, and at the bottom.

The temperatures were observed for several days. It was noted that although the temperature on the bottom of the inner tank followed a diurnal cycle of about $4^{o}C$, the temperature on the bottom of the outer tank remained constant. The temperatures at the halfway point of the outer tank also followed a diurnal cycle, of about $2^{o}C$. This was probably due to transfer of heat by the metal from the exposed rim to the buried thermocouple, which was taped to the side of the tank. Figure 3 shows the 24-hour variation of some of the observed temperatures. Only one of the side temperatures on the outer tank is shown since they were all essentially the same. The effectiveness of the insulation in minimizing heat flow is clearly illustrated by the constant temperature at the bottom of the outer tank. This indicates that heat transfer through the side and bottom was small and can be neglected.

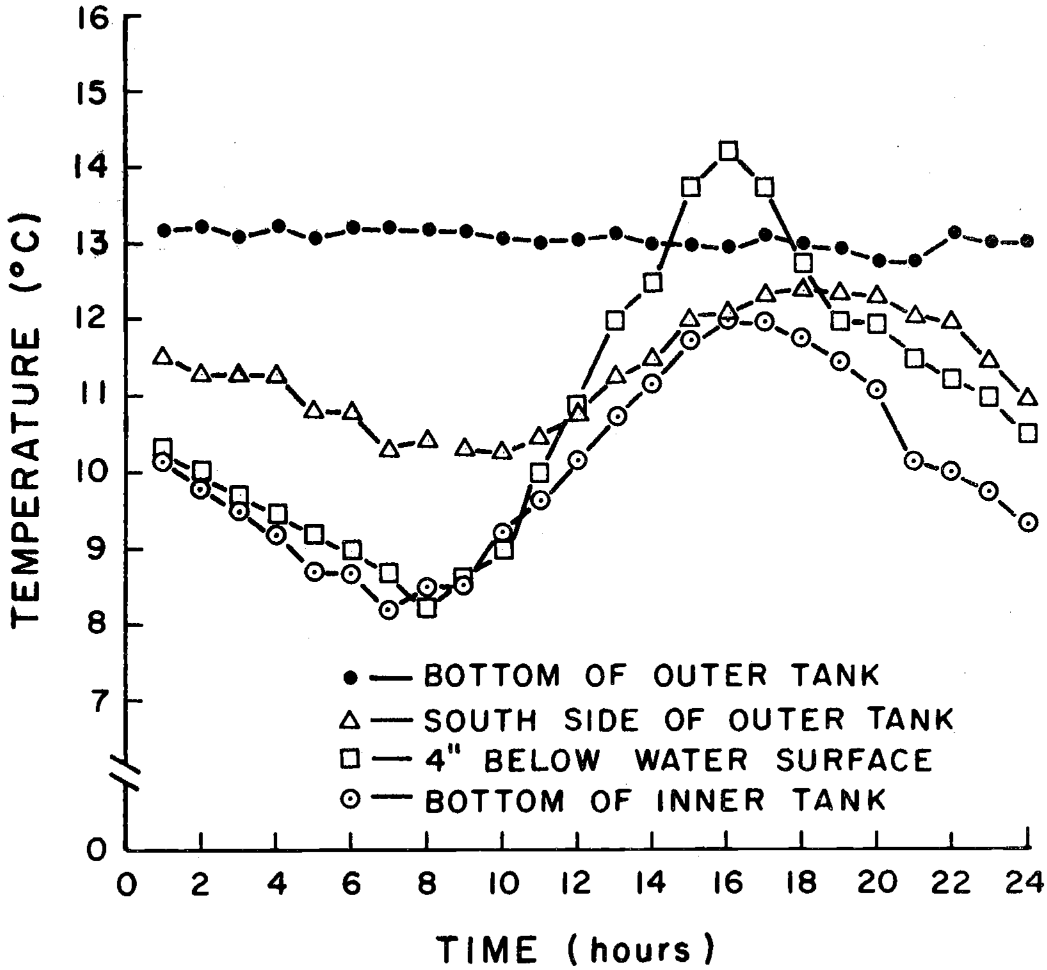

Figure 3.--Temperature at selected locations on tank #4 Feb. 21, 1967.

EXPERIMENTAL ANALYSIS AND PROCEDURE

Evaluation of Evaporation Equations. In order to determine a complete heat balance on an hourly basis, it was necessary to compute hourly evaporation for the 1967 studies, since water stage recorders were not sufficiently sensitive. This necessitated the selection of an evaporation equation, a number of which are available in the literature, for use in this study.

Several researchers have compared some of the various evaporation equations (Conaway and Van Bavel, 1967; Fritschen and Van Bavel, 1963b; Pruitt, 1963 and 1966). It was found that one equation would be more accurate in some cases, while another would yield better results under different conditions. It was therefore necessary to evaluate several of the evaporation equations under the particular conditions of this study to determine the equation that would produce the most representative values.

Four equations were evaluated (two Dalton-type, Bowen ratio, and combination) using measured evaporation on the open tank as a standard. The first equation evaluated was a Dalton-type expression of the form

$$E = \left(\frac{\rho\delta}{P}\right) (e_s - e_a)\ f(U) \qquad [11]$$

in which

δ = water vapor/air molecular weight ratio (0.622)

P = ambient pressure (970 mb)

f = wind or transfer function

and other terms are as previously defined.

According to Sverdrup (1946) and others, f(U) can be evaluated by the relationship:

$$f(U) = \frac{k^2 U}{[\ell n\,(z/z_o)]^2} \quad . \qquad [12]$$

The second equation evaluated was also a Dalton-type expression except that the value of f(U) was obtained as suggested by Sheppard (1958) by writing

$$f(U) = kU^* \, [\ell n(kU^* z/D)]^{-1} \qquad [13]$$

in which

U^* = friction velocity (cm sec^{-1})

D = diffusivity of water vapor in air (0.24 cm^2 sec^{-1}).

The friction velocity is defined as

$$U^* = \frac{kU}{\ell n(z/z_o)} \quad . \qquad [14]$$

The third equation evaluated is a combination of the energy balance equation and the ratio of sensible heat to latent heat, or the Bowen ratio (Bowen, 1926). This equation, which assumes horizontal divergences of sensible and latent heat between the levels of measurement to be zero, can be used to estimate evaporative flux from a water surface. Expressed in present notation it is:

$$LE = \frac{Rn - G}{1 + \gamma\ (T_w - T_a)/(e_s - e_a)} \qquad [15]$$

where

γ = psychrometer constant (0.642 mb deg^{-1}).

The final equation, proposed by Van Bavel (1966), is referred to as the combination method of determining evaporative flux. It is related to both the Dalton-type expression and the Bowen ratio model and is written as:

$$LE = \frac{\Delta/\gamma\ H + LBvda}{\Delta/\gamma + 1} \qquad [16]$$

in which

Δ/γ = a temperature dependent dimensionless number

H = Rn - G

Bv = transfer coefficient for water vapor

da = vapor pressure deficit of the air at elevation z.

The definition of Bv is given as:

$$Bv = \frac{\rho \; \delta \; k^2}{P} \; \frac{U}{[\ell n(z/z_o)]^2} \quad . \qquad [17]$$

Hourly evaporation values were calculated by using equations [11], [15] and [16] for two different periods, and compared to measured evaporation values obtained from the water stage charts for the open tank. The comparison periods were selected on the basis of two criteria, cloud cover and steady state conditions. Cloud cover affects the radiation readings, and representative values may not be recorded on cloudy days. Steady state conditions in this case refers to the atmospheric conditions being about the same on each day, in other words, no frontal activity or other rapid changes.

Results of the calculations are presented in Table 4, and the percent error shown is calculated with respect to the measured values. Of the four equations evaluated, the combination method as suggested by Van Bavel (1966) gave the best results under the conditions of this study. Even this method, however, produced errors for the 12-hour periods as high as 26 percent. The combination method was selected to be used for further calculations because the errors based on the totals for the two comparison periods were small.

Evaporation as calculated by the Bowen ratio method was generally low, and errors as high as 32 percent were noted for the 12-hour

Table 4

Comparison of calculated and measured evaporation on open tank (cm)

Date	Time	Emeas	E_d	% Error	E_s	% Error	E_{BR}	% Error	E_c	% Error
20 Sep	00-12	.24	.20	-16	.14	-42	.27	14	.25	5
	12-24	.31	.23	-26	.18	-40	.22	-27	.23	-26
21 Sep	00-12	.22	.17	-22	.12	-45	.27	20	.23	4
	12-24	.49	.51	4	.33	-33	.33	-32	.38	-23
22 Sep	00-12	.28	.50	78	.31	9	.29	4	.35	24
	12-24	.66	.97	48	.59	-10	.53	-19	.63	- 4
23 Sep	00-12	.27	.28	3	.18	-32	.25	- 8	.27	0
	12-24	.61	1.01	66	.61	0	.45	-27	.59	- 3
Total		3.08	3.87	27	2.46	-20	2.61	-15	2.93	- 5
27 Sep	00-12	.33	.38	17	.24	-26	.31	- 5	.30	- 8
	12-24	.62	.98	59	.58	- 6	.48	-22	.65	5
28 Sep	00-12	.31	.33	6	.21	-31	.32	3	.32	3
	12-24	.45	.75	67	.46	2	.38	-16	.49	8
29 Sep	00-12	.28	.29	4	.19	-31	.24	-15	.26	- 7
	12-24	.30	.40	36	.27	-10	.26	-14	.30	0
30 Sep	00-12	.25	.25	0	.17	-31	.24	- 4	.25	0
	12-24	.34	.58	69	.37	8	.28	-17	.41	20
Total		2.88	3.96	38	2.49	-13	2.51	-13	2.98	3

E_d - Dalton-type expression with f(U) evaluated by Sverdrup method.

E_s - Dalton-type expression with f(U) evaluated by Sheppard method.

E_{BR} = Bowen Ratio Method

E_c = Combination Method

periods. A previous study in the same area showed that this method compared well with evaporative flux from a cropped surface (Fritschen, 1965b). The two remaining methods were considerably in error as shown in the table.

The reason for the rather large differences in calculated evaporation, as determined by the methods evaluated, is not immediately apparent. The fact that the Dalton-type expression, using the transfer function suggested by Sverdrup (1946), produced the poorest results is particularly puzzling since this same expression is contained in the combination equation, which produced the best results. A re-examination of the equations revealed that small errors in measurement of the surface temperature could cause large errors in calculated evaporation (Conaway and Van Bavel, 1966). For example, small errors in surface water temperature measurements will produce considerably larger errors in the calculated saturation vapor pressure because of the exponential relationship between them. Writing the Dalton-type expression, using the transfer function suggested by Sverdrup (1946),

$$LE = LBv\ (e_s - e_a) \qquad [18]$$

we note that errors in temperature measurement will be magnified since calculated evaporation is directly proportional to the vapor pressure difference.

If we substitute the above relationship into the Bowen ratio equation and rearrange terms, we obtain:

$$LE = (Rn - G) - LBv\ \gamma(T_w - T_a) \quad . \qquad [19]$$

In this case, errors in the surface water temperature measurement will be reflected in the calculated evaporation. However, these errors are smaller than the saturated vapor pressure errors. These errors will be dampened somewhat due to the inclusion of the net radiation and heat storage terms, the combination of which is generally greater than the sensible heat transfer term. The factor γ being less than unity also dampens temperature errors.

Again substituting equation [18], as well as the Clausius-Clapeyron equation (Sellers, 1965), into the Bowen ratio equation, we obtain the combination equation written as:

$$LE(1 + \gamma/\Delta) = (Rn - G) - LBv\ \gamma/\Delta(da) \quad . \qquad [20]$$

Use of the Clausius-Clapeyron equation eliminates the surface water temperature and errors associated with it. Errors associated with the assumptions involved in this substitution will also be dampened since γ/Δ is less than unity in all cases considered here.

Since the transfer parameter (Bv) appears in the same term as the vapor pressure (or temperature) difference in all three equations, errors in this parameter would have the same relative effect on calculated evaporation as errors involved in surface temperature measurements.

From the above discussion, we note that the Dalton-type expression is more sensitive to errors in either the surface temperature measurements or the transfer parameters. Furthermore, the combination equation is less sensitive then the Bowen ratio method. Differences noted between the Bowen ratio, Dalton, and combination equations can probably be explained on the basis of sensitivity to errors in surface temperature measurements.

A representative example of the variation in calcuated evaporation by the four methods evaluated is presented in Figure 4 for September 23, 1967.

The data used to evaluate these equations, and the data used in subsequent calculations, are presented in the Appendix. Each table contains general meteorological data as well as data pertaining to individual tanks for each hour of the days investigated. In most cases these data are smoothed values obtained from lines fitted by eye through half-hourly measured values.

The value of the roughness parameter used was obtained from wind profile measurements observed over each of the tanks. The values obtained varied from about 1.0 to 0.6 cm, and an average value of 0.8 cm

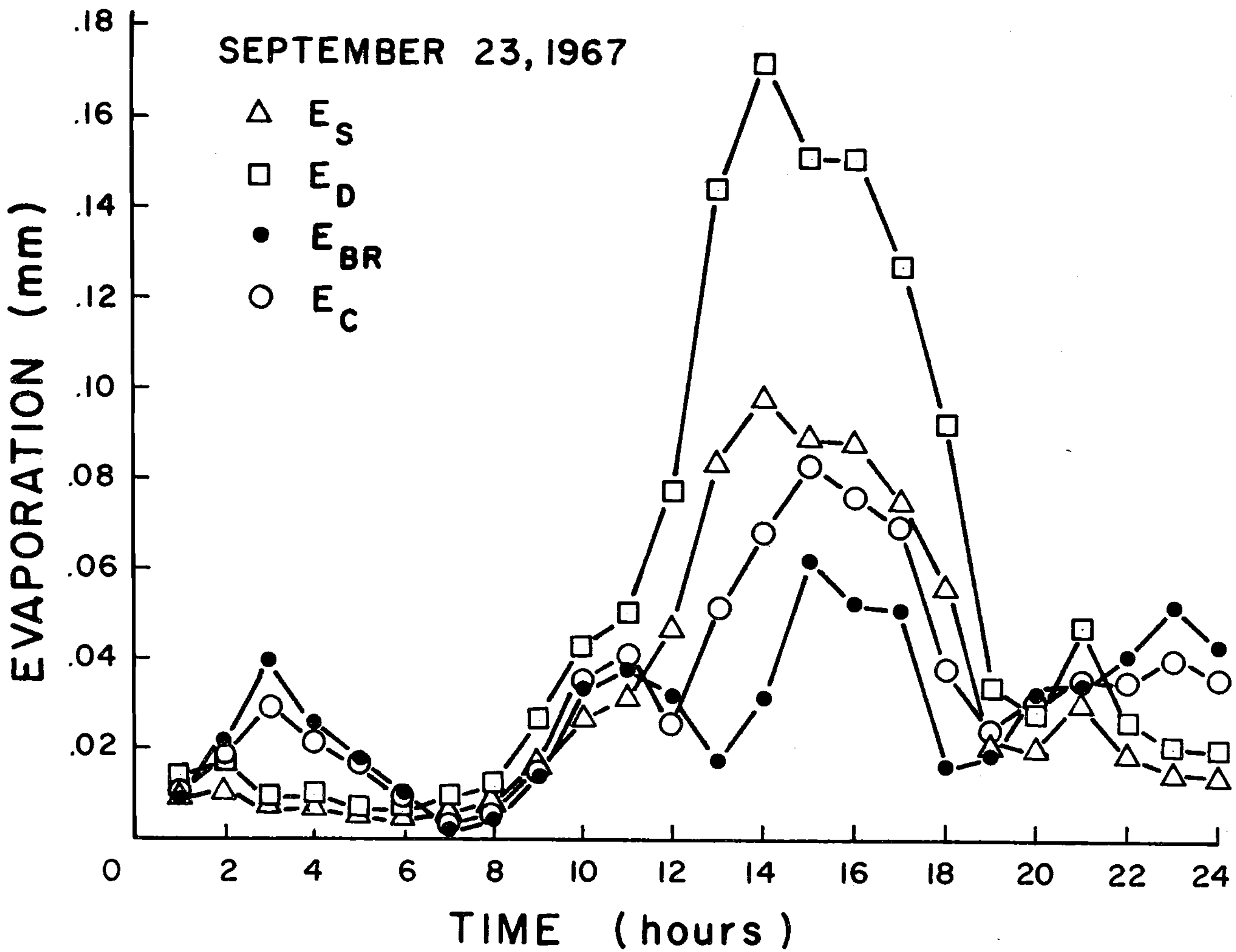

Figure 4.--Hourly variation of evaporation as calculated by two Dalton-type expressions (E_s,E_d), the Bowen Ratio method (E_{BR}), and the combination method (E_c).

was used for all tanks and covers. This value agrees well with those listed by other investigators for short grass (Tanner and Pelton, 1960; Van Wijk, 1963).

The wind speed, air temperature, and dew point were measured at the 1 meter level. Using the air temperature, values of Δ/γ were obtained from a table given by Van Bavel (1966, p. 467). The value of other parameters were listed following their definition.

<u>Derivation of Modified Combination Equation</u>. The combination method, as presented, is designed to estimate evaporation from an open water surface. It was therefore necessary to modify the equation when considering evaporation from a partially covered tank. The modification is necessary since the reduction in evaporation on the partially covered tanks may not be proportional to the percentage of the area covered, or to any other known cover property.

Following a similar procedure and reasoning as that used by Van Bavel (1966), with the exception that each step is adjusted to pertain to the substance concerned and percentage of total area involved, the derivation of the modified equation is as follows.

The latent heat transport from the water surface to elevation z can be defined as

$$LE = LBv\ (e_s - e_a)\ \text{cal cm}^{-2}\ \text{min}^{-1} \qquad [21]$$

Because sensible heat transfer may occur from both the water surface and the cover surface, but at different rates, each will be discussed separately.

Assuming similarity between vapor and sensible heat transport, we have

$$A_c = \gamma\ LBv\ (T_c - T_a)\ \text{cal cm}^{-2}\ \text{min}^{-1} \qquad [22]$$

where A_c is the sensible heat transport in the units shown. This equation describes sensible heat transfer from the surface of the cover.

For the open water portion, using primes to indicate saturated values, we can write

$$(T_w - T_a) = (e_s' - e_a')/\Delta \qquad [23]$$

Substituting this relationship into equation [22] above, we obtain an expression for sensible heat transfer from the water surface

$$A_w = \gamma/\Delta \ LBv \ (e_s' - e_a') \quad . \qquad [24]$$

Combining the above terms, and taking into account the percentage of area covered, we obtain the expression for sensible heat transport from the entire surface area,

$$A = \gamma/\Delta \ (1-p) \ LBv \ (e_s' - e_a') + \gamma p \ LBv \ (T_c - T_a) \qquad [25]$$

where p refers to the percentage (expressed as a decimal) of water surface covered.

If we now add and subtract e_a, we obtain

$$A = \gamma/\Delta\ (1-p)\ LBv\ (e_s'-e_a) - \gamma/\Delta\ (1-p)\ LBv\ (e_a'-e_a) + \gamma p\ LBv\ (T_c-T_a) \qquad [26]$$

Since $e_a' - e_a$ is equal to the vapor pressure deficit (da) at elevation z, and by considering $e_s = e_s'$ as the defining condition for potential evaporation or evaporation from an open water surface, we have

$$A = \gamma/\Delta\ LE - \gamma/\Delta\ LBv\ (1-p)\ da + \gamma p\ LBv\ (T_c-T_a) \qquad [27]$$

in which $E = Bv\ (e_s'-e_a)$.

Substituting this expression into the energy balance equation ($LE + A - H = 0$) and rearranging terms we obtain the equation for estimating evaporation from a partially covered body of water, by the modified combination method, written as

$$E = \frac{(\Delta/\gamma)\ H/L - Bv\ (1-p)\ da + \Delta p B_v\ (T_c-T_a)}{\Delta/\gamma + 1} \qquad [28]$$

where $H = Rn - G - Q$ and Q is the energy stored within the cover. This equation is general in nature and should apply to any type of cover material of which the impervious area is known.

Using the above equation, hourly evaporation values were calculated for the tanks partially covered by the four different materials previously described. As a means of checking the calculations for the 1967 study, the hourly values were summed for 24-hour periods and compared to the daily evaporation as recorded on the water stage charts. The results of these comparisons are presented in Table 5.

The evaporation data for September 23 and 27-30, 1967, which were in Table 4 for the open tank, are presented again in Table 5, except on a 24-hour basis. These values, as well as those for October 18-20, 1967, are presented for comparison purposes, and indicate that the results obtained by the combination method on the open tank remained essentially the same for the entire period.

Since conditions and results on each tank are different, the results presented in Table 5 will be discussed separately and with respect to the type of cover rather than the number of the tank. It should also be noted that the possible magnitude of measurement error is the same for all tanks and may be as high as $\pm$ 0.5 mm. This value applies to either individual days or groups of days because of the techniques used in reading the charts. It is due to the nonsensitivity of the water stage recorders. These recorders would sometimes record a steplike trace, when in fact, evaporation had been taking place during the entire period, but the pen arm would only drop after a certain minimum friction or elevation change had been exceeded.

Table 5
Comparison of measured and calculated evaporation values on all tanks 1967 (cm)

Tank & Cover Material	Parameter	Sep 1967 23	27	28	29	30	Total 27-30	Oct 1967 18	19	20	Total 18-20
Tank #1	Evap Meas	.23	.21	.21	.13	.19	.74	.14	.11	.16	.41
Foamed Wax	Evap Cal	.20	.26	.20	.15	.21	.82	.17	.15	.18	.50
Blocks	% Diff.	-13	24	-5	15	11	11	21	36	13	22
(78%)	Diff.	.03	.05	.01	.02	.02	.08	.03	.04	.02	.09
Tank #2	Evap Meas	.21	.20	.11	.14	.13	.58	.05	.09	.09	.23
Butyl Rubber	Evap Cal	.17	.17	.15	.14	.18	.64	.11	.08	.11	.30
(86%)	% Diff.	-19	-15	36	0	38	10	120	-11	22	30
	Diff.	.04	.03	.04	0	.05	.06	.06	.01	.02	.07
Tank #3	Evap Meas	.88	.95	.76	.58	.60	2.89	.50	.49	.51	1.50
Open Water	Evap Cal	.86	.95	.81	.56	.66	2.98	.59	.48	.55	1.62
-	% Diff.	-2	0	7	-3	10	3	18	-2	8	8
	Diff.	.02	0	.05	.02	.06	.09	.09	.01	.04	.12
Tank #4	Evap Meas	.46	.38	.32	.21	.33	1.24				
Lightweight	Evap Cal	.42	.44	.36	.27	.31	1.38				
Concrete	% Diff.	-9	16	13	29	-6	11				
Blocks (Sep)	Diff.	.04	.06	.04	.06	.02	.14				
(78%)											
Styrofoam								.12	.09	.15	.36
(Oct)								.15	.16	.16	.47
(80%)								25	78	7	31
								.03	.07	.01	.11

The covers on Tank #1 for the entire period, and Tank #4 for the period September 23 and 27-30, consisted of many individual pieces of the materials noted in the table. The results show that during September the maximum error on Tank #1 was 24 percent, or 0.05 cm, with an average for the period September 27-30 of 11 percent, or .08 cm, total difference. On Tank #4 for this same period, the maximum error was 29 percent, or 0.06 cm, with the average for September 27-30 being 11 percent, or 0.14 cm, total difference. For the period October 18-20 on Tank #1, the maximum error was 36 percent, or 0.04 cm, for a single day, and the average for the period was 22 percent, or 0.09 cm, total difference. In other words, the calculated value for any of these days is well within the limits of measurement capabilities; however, the total for the periods mentioned is slightly more than can be accounted for by measurement error alone. These results would indicate that the modified equation has a tendency to slightly over-estimate evaporation from the covered tanks. However, even the worst results could be well within the usually sought for 10 percent range if only a portion of the possible measurement error was subtracted from the total difference (or added to the measured evaporation). The fact that evaporation was quite low during the latter part of the study also tends to make results look worse when they are expressed in percent.

The covers on Tank #2, for the entire period, and Tank #4, for the October 18-20 period, consisted of single pieces or membranes of the materials noted in the table. The maximum error on Tank #2 during September is 38 percent, or 0.05 cm, and the average for the period September 27-30 is 10 percent, or 0.06 cm total difference. For the period October 18-20, the maximum error is 120 percent, or 0.06 cm, and the average for the period is 30 percent, or 0.07 cm, total difference. On Tank #4 during the period October 18-29, the maximum error is 78 percent, or 0.07 cm, with an average for the period of 31 percent, or 0.11 cm, total difference.

In this case, two of the eleven daily values cannot be accounted for by water level measurement error alone. However, all of the values for the three or four day periods except that on Tank #4 for 18-20 October could be within the desired 10 percent range if possible water level measurement errors were taken into account. Again, the equation tends to over-estimate evaporation. Although water level measurement error may be of sufficient magnitude to explain the errors noted, the differences may be due to errors in the radiation and temperature profile measurements. For example, in both cases where membrane type covers were used, the net radiation measured was biased toward the reflective properties of the cover rather than the water. Since the cover represented about 80 percent of the surface area and the radiometer is more sensitive to objects directly below it (95 percent of its reading is based on objects within a 120° envelope from the sensing element due to cosine response), even if some of the water was visible to the radiometer due to its placement, the effect of the water on the reading would be much less than

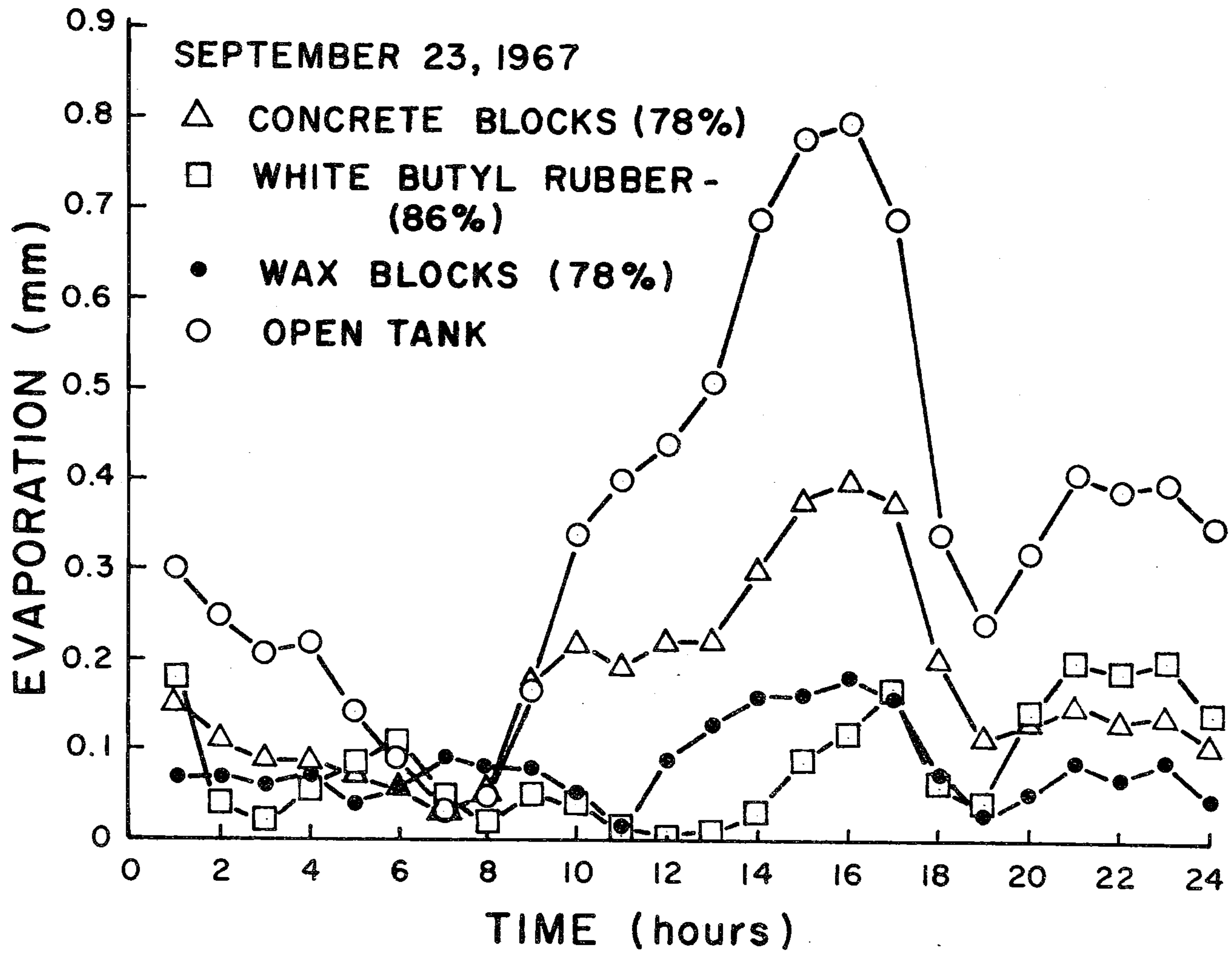

Figure 5.--Hourly variation of evaporation as calculated by combination method for open tank, and modified combination method for covered tanks.

20 percent. The temperature profiles were obtained by placing thermocouples on a stand at different levels within the tank. This stand was placed at the edge of the cover, or near the edge of the tank, and may not represent average conditions within the tank. It would be affected by sunlight entering the water and may be more representative of open water conditions than average conditions.

A representative example of the hourly variation of evaporation as calculated for the four study tanks is presented in Figure 5 for September 23, 1967.

As further verification of the modified combination equation, evaporation was also calculated for the 1968 studies. The results of these calculations, as compared to water level measurements obtained by the capacitance probe, are presented in Table 6. As noted, about half of the calculations are within the desired 10 percent range of measured values, and most of the others are only slightly higher. Since in this case water level measurements are much more accurate than those obtained by water stage recorders, the observed differences are probably due to other factors. Again the representativeness of the water profile measurements may be questioned; however, net radiation is more likely in error in this case. Net radiation measurements for this study were quite variable and for the above calculations, computed net radiation values were used. These computed values were based on measurements of net radiation on the open tank, and average albedo values obtained during both 1967 and 1968 (the method of computing

Table 6

Comparison of measured and calculated evaporation on all tanks 1968 (cm)

Date		Aug 1968										
Tank	Day	1	2	Total 1 & 2	14	15	16	Total 14-16	22	23	24	Total 22-24
Tank #1	Cover (%)	White Butyl (86%)			Styrofoam (87%)				Styrofoam (87%)			
	Evap Meas	.10	.09	.19	.16	.12	.16	.44	.14	.11	.09	.34
	Evap Cal	.14	.13	.27	.18	.15	.17	.50	.16	.12	.08	.36
	% Diff	40	44	42	13	25	6	14	14	9	-11	6
	Diff	.04	.04	.08	.02	.03	.01	.06	-02	.01	.01	.02
Tank #2	Cover (%)	Open			Open				Open			
	Evap Meas	.79	.75	1.54	.89	.64	.89	2.42	.80	.60	.62	2.02
	Evap Cal	.88	.79	1.67	.93	.66	.95	2.54	.89	.58	.69	2.16
	% Diff	11	5	8	4	3	7	5	11	-3	11	7
	Diff	.09	.04	.13	.04	.02	.06	.12	.09	.02	.07	.14
Tank #3	Cover (%)	Styrofoam (80%)			Styrofoam (51%)				Styrofoam (76%) - 1 Hole			
	Evap Meas	.15	.19	.34	.54	.35	.50	1.39	.23	.20	.13	.56
	Evap Cal	.14	.12	.26	.61	.47	.62	1.70	.25	.22	.14	.61
	% Diff	-7	-.37	-24	13	34	24	22	9	10	8	9
	Diff	.01	.07	.08	.07	.12	.12	.31	.02	.02	.01	.05
Tank #4	Cover (%)				Styrofoam (26%)				Styrofoam (76%) - 12 Hole			
	Evap Meas				.77	.54	.73	2.04	.25	.23	.17	.65
	Evap Cal				.76	.58	.83	2.17	.29	.23	.22	.74
	% Diff				-1	7	14	6	16	0	29	14
	Diff				.01	.04	.10	.13	.04	0	.05	.09

net radiation will be discussed in more detail in the next section). It should also be noted that evaporation was very low on the tanks with large covers, and actual differences between calculated and measured evaporation were less than those on the open tank for the same period.

The greatest differences (.07, .12, .12) between calculated and measured evaporation were obtained for the 51 percent styrofoam cover on August 14-16. Since the modified combination method produced good results in all other cases tested, this discrepancy could have been caused by a non-representative temperature measurement, or a combination of errors, neither of which was obvious during the experiment or calculations.

From the above calculations, using four different cover materials and several different sizes, it is concluded that the equation as modified is valid for computing evaporation from partially covered tanks. The results of such calculations should be within 10 percent of the measured values if measurements are representative of average conditions.

Use of Insulated Tanks. The use of insulated evaporation tanks in these studies provides several advantages over other types. The evaporation from an insulated tank more nearly represents evaporation from ponds or small lakes since heat exchange through the sides and bottom is negligible. Energy balance investigations are also simplified when heat exchange from the sides and bottom can be neglected.

Being able to neglect this one heat exchange term also provides an easy and accurate method of determining long-wave radiation from the atmosphere, and net radiation over other surfaces where albedos are known (Harbeck, 1954; Anderson and Baker, 1967; Kohler and Parmele, 1967).

Net radiation over the open tank and measured albedos were used in the 1968 studies to compute net radiation over the covered tanks. Neglecting the reflected long-wave radiation term, which is very small for water surfaces and most cover surfaces, the net radiation for an open tank is expressed as

$$Rn = Ra + S - \varepsilon_w \sigma T_w^4 - r_w S \quad . \qquad [29]$$

For the partially covered tank the expression is:

$$Rn_c = Ra + S - [1-p)r_w + pr_c]S - \sigma[\varepsilon_w (1-p)T_{w_c}^4 + \varepsilon_c p T_c^4] \quad . \qquad [30]$$

Since atmospheric radiation is the same for both tanks, the two equations can be combined by eliminating this term. Solving for the net radiation over the covered tank we obtain:

$$Rn_c = Rn + \sigma[\varepsilon_w T_w^4 - \varepsilon_w(1-p)T_{w_c}^4 - \varepsilon_c p T_c^4] + pS[r_w - r_c] \qquad [31]$$

All of the parameters in this equation were either known or measured, thus allowing computation of net radiation over the partially covered tank (Rn_c). The calculated values for 1968 are presented with the other hourly data in the Appendix. The agreement of measured and calculated evaporation shown in Table 6 is an indication of the validity of these computed values of net radiation. As an example of the need for these calculations, the net radiation as measured and calculated for two tanks on two different days is presented in Table 7. The net radiation over the open tank is also shown for comparison purposes. The reason the measured values are not always representative is that the radiometer does not always view the correct proportion of cover and water. This occurs because wind action moves the cover away from the net radiometer position part of the time. At other times the radiometer views only the cover surface and readings are again nonrepresentative. Observation of Table 7 will show some readings over the covered tanks to be essentially the same as those over the water surface of the open tank. This is particularly true on Tank #4 on August 15, 1968. In other cases the readings are much smaller - notice Tank #3 on August 15, 1968. If the readings are representative, they should be an essentially constant percentage less than those on the open tank during the daylight hours. This percentage, of course, depends on the area covered and the reflective properties of the cover. Covers

Table 7

Comparison of measured and calculated net radiation over covered tanks (ly/min)

	15 Aug 1968					23 Aug 1968				
	Tank #3 Styrofoam (51%)		Tank #2 Open	Tank #4 Styrofoam (26%)		Tank #3 Styrofoam (76%) 1-hole		Tank #2 Open	Tank #4 Styrofoam (76%) 12-hole	
Time	Rn cal	Rn meas	Rn meas	Rn cal	Rn meas	Rn cal	Rn meas	Rn meas	Rn cal	Rn meas
1	-.09	-.04	-.15	-.11	-.15	-.06	-.10	-.15	-.06	-.05
2	-.09	-.04	-.14	-.11	-.15	-.07	-.10	-.16	-.07	-.07
3	-.09	-.06	-.14	-.11	-.14	-.07	-.11	-.15	-.07	-.07
4	-.10	-.05	-.14	-.12	-.14	-.06	-.11	-.15	-.06	-.07
5	-.09	-.06	-.13	-.11	-.14	-.06	-.11	-.15	-.06	-.07
6	-.09	-.05	-.12	-.11	-.13	-.06	-.11	-.14	-.06	-.07
7	.01	-.01	.09	.05	-.04	-.03	-.02	-.05	-.03	-.00
8	.13	.02	.36	.24	.38	.02	.21	.32	.02	.06
9	.28	.09	.64	.46	.67	.12	.42	.66	.12	.20
10	.41	.11	.87	.64	.93	.19	.52	.85	.19	.22
11	.50	.13	1.03	.76	1.04	.26	.68	1.02	.26	.25
12	.52	.15	1.10	.81	1.13	.31	.74	1.13	.31	.35
13	.54	.14	1.11	.82	1.11	.36	.77	1.18	.36	.41
14	.51	.13	1.04	.77	1.04	.33	.74	1.10	.33	.32
15	.42	.08	.88	.65	.81	.26	.60	.94	.26	.22
16	.30	.01	.65	.48	.60	.17	.41	.69	.17	.16
17	.16	.02	.38	.28	.33	.07	.21	.36	.07	.04
18	.04	-.01	.11	.08	-.09	.01	.11	.19	.01	.04
19	-.05	-.06	-.09	-.07	-.08	-.06	-.06	-.10	-.06	-.04
20	-.07	-.04	-.12	-.10	-.12	-.05	-.07	-.11	-.05	-.04
21	-.07	-.04	-.13	-.09	-.12	-.05	-.07	-.11	-.05	-.05
22	-.07	-.04	-.13	-.10	-.13	-.06	-.07	-.12	-.06	-.04
23	-.07	-.05	-.13	-.09	-.13	-.05	-.08	-.12	-.05	-.06
24	-.07	-.05	-.13	-.09	-.13	-.05	-.08	-.12	-.05	-.06
60Σ	172	17	403	290	381	82	259	409	82	95

such as the styrofoam cover with 12 holes, or the wax blocks, are not usually a problem since the radiometer views a representative sample all the time. This is shown in Table 7 where measured and calculated values are seen to be essentially the same for the 12-hole cover. The 1-hole styrofoam cover should receive about the same net radiation since the area covered and albedo are the same. However, in this case the readings are biased towards the open water portion in the center due to the placement of the radiometer.

The hourly albedos of the cover materials investigated are presented in Table 8 for the period of daylight. This table was derived from plots of half-hourly measured values recorded at various times throughout both the 1967 and 1968 studies.

If equation [29] is rearranged, the long-wave atmospheric radiation can be determined since all of the other parameters are either known or measured.

$$Ra = Rn - S + \varepsilon_w \sigma T_w^4 + r_w S \quad . \qquad [32]$$

Long-wave radiation on September 29, 1967, as calculated by this method, is presented in Table 9 for both the open and partially covered tanks. Although the values obtained from open tank data are undoubtedly more accurate, the other values are in good agreement with them. The values obtained from the partially covered tanks are subject to more error

Table 8

Average Albedo of cover materials

Time	Wax Blocks	White Butyl	Styrofoam	Cement Blocks	Open Water
6	.99	.99	.98	.99	.43
7	.82	.88	.90	.55	.21
8	.72	.80	.84	.46	.13
9	.66	.75	.81	.43	.10
10	.64	.73	.79	.41	.09
11	.62	.72	.78	.40	.08
12	.62	.71	.77	.40	.077
13	.63	.71	.77	.40	.077
14	.65	.72	.78	.40	.08
15	.67	.73	.80	.41	.09
16	.70	.75	.82	.46	.11
17	.74	.80	.86	.55	.15
18	.83	.88	.91	.69	.25
19	.99	.99	.98	.99	.52
Σ	10.28	11.16	11.79	7.54	2.40
Avg.	.73	.80	.84	.54	.17

Table 9
Longwave Radiation Calculations
September 29, 1967 (ly/min)

Time	Wax Blocks	White Butyl	Open	Cement Blocks
1	.50	.52	.53	.53
2	.50	.51	.52	.53
3	.51	.51	.52	.53
4	.50	.50	.49	.52
5	.49	.50	.51	.52
6	.49	.50	.51	.52
7	.49	.50	.51	.52
8	.56	.59	.54	.51
9	.60	.64	.55	.59
10	.63	.65	.59	.62
11	.65	.66	.62	.61
12	.67	.66	.63	.61
13	.68	.65	.63	.61
14	.66	.65	.67	.57
15	.68	.57	.62	.58
16	.65	.56	.62	.55
17	.64	.59	.61	.58
18	.61	.58	.62	.60
19	.55	.56	.56	.57
20	.55	.55	.55	.56
21	.53	.53	.51	.54
22	.54	.55	.55	.57
23	.54	.55	.55	.57
24	.53	.53	.54	.54
60Σ	825	817	813	806

since more measurements are required and net radiation is subject to the same limitations as mentioned above. The 813 langleys per day obtained by this method is within reason when compared to values obtained by Koberg (1964) by another method. His values for both Lake Mead and Roosevelt reservoir range between 650 and 820 langleys per day for the same season during the 1950's.

RESULTS AND DISCUSSION

The objectives of this study were to determine the physical properties that should be considered in the design of floating covers used to reduce evaporation from water surfaces, and to obtain a better understanding of the evaporation process from a partially covered body of water. Results of the study that pertain to these objectives are presented and discussed in this section. Where possible, the results are compared with those of previous investigators. However, due to a lack of studies of this type, this is possible in only a few cases. The significant findings of each aspect of the study are also pointed out.

Energy Balance of Tanks. Daily totals of the parameters in the energy balance equation are presented for the 1967 study in Table 10. These values were obtained by measuring the net radiation and evaporation, and calculating the energy in storage in the water and cover. The sensible heat term was then determined as the residual in the energy balance equation. This method of determining the sensible heat transfer has some disadvantages since all errors in the other terms of the energy balance equation are accumulated in the residual term. However, other methods to determine the sensible heat transfer (A) have also been shown to be considerably in error at times (Conaway and Van Bavel, 1966). Therefore, the above method is probably as good or better than any other available.

Table 10

Energy balance results on a 24-hour basis, 1967 (ly/day)

Tank and Cover Material	Date / Term	Sep 1967 23	Sep 1967 27	Sep 1967 28	Sep 1967 29	Sep 1967 30	Oct 1967 18	Oct 1967 19	Oct 1967 20
Tank #1 Foamed Wax Blocks (78%)	Rn	122	114	107	73	72	56	52	56
	G	-13	27	3	4	19	4	2	8
	Q	0	0	0	0	0	-2	0	-4
	LE	-134	-125	-121	-76	-111	-80	-62	-93
	A	25	-16	11	-1	20	22	8	33
Tank #2 Butyl Rubber (80%)	Rn	137	103	94	90	86	59	55	59
	G	-31	25	11	4	6	-23	9	1
	Q	0	0	0	0	0	0	0	0
	LE	-120	-116	-62	-80	-75	-31	-54	-53
	A	14	-12	-43	-14	-17	-5	-10	-7
Tank #3 Open Water	Rn	366	349	340	328	316	256	202	259
	G	4	48	12	-62	-14	-37	1	-4
	LE	-511	-551	-444	-338	-347	-293	-285	-298
	A	141	154	92	72	45	74	82	43
Tank #4 Lightweight Concrete Blocks Sep (78%)	Rn	189	182	169	164	145			
	G	2	15	-6	-21	-2			
	Q	1	-1	-1	-3	-1			
	LE	-271	-222	-187	-124	-191			
	A	79	26	25	-16	49			
Styrofoam Oct (80%)	Rn						20	17	18
	G						5	28	17
	Q						0	0	0
	LE						-71	-54	-89
	A						46	9	54

The sign convention used in this section of the study is as follows:

Rn is positive when energy is being added to the water.

G is positive when the average water temperature is decreasing, since the energy is then available for use in the evaporation process.

Q is positive when the average cover temperature is decreasing.

LE is negative when evaporation is occurring.

A is positive when heat is flowing from the air to the water.

It is obvious from the results presented in Table 10, that the net radiation and evaporation terms are by far the largest, except for the styrofoam cover, in which case the evaporation and sensible heat transfer terms are the largest. From these results, it would appear that generally the way to influence the evaporation term (LE) the most, would be to change the net radiation term (Rn). Small changes in the reflective properties would have a much greater effect on the evaporation term than would small changes in the sensible heat transfer characteristics, since for all covers except the styrofoam, it is of rather minor importance.

The heat stored in the cover is noted to be less than 4 percent of the evaporation term in all cases, and in fact, it is zero in most cases. Because of the small magnitude of this term, it was neglected in all of the 1968 studies. If other cover materials are used, however, this term should be investigated.

Daily totals of the parameters in the energy balance equation are presented in Table 11 for the 1968 studies. In this table the net radiation values were computed as noted in the previous section. These data again indicate that, except for the large styrofoam cover, the net radiation and evaporation are of greatest magnitude.

It is interesting to note that in most cases, for both the 1967 and 1968 studies, the sensible heat transfer is positive. This means that energy is being transferred from the atmosphere to the water, and is therefore available for use in the evaporation process. In the case of the open water and the white butyl cover, this term is negative about 1/4 to 1/3 of the time, indicating energy is being transferred to the atmosphere, thus decreasing the energy available for evaporation. This could indicate that if the albedo of the styrofoam and butyl were the same, and if they both covered the same surface area, the butyl would be more efficient in reducing evaporation. Data to verify this assumption, however, are not available.

The results of the energy balance calculations are also presented in graphical form in Figures 6 through 16. The hourly values of evaporation used in the 1967 graphs are calculated using the modified combination method. Totals will therefore differ slightly from those presented in Table 10, which are based on evaporation measurements as recorded by the water stage recorders. These graphs show the hourly variations and magnitudes of the energy balance parameters, revealing considerably more than the daily totals presented in the tables.

Table 11

Energy balance results on a 24 hour basis, 1968 (ly/day)

Tank	Variable Date	1	2	14	15	16	22	23	24
				AUGUST	1968				
	Cover & % Area	White Butyl	(86%)	Styrofoam		(87%)	Styrofoam		(87%)
Tank #1	Rn	125	141	31	20	33	34	29	29
	G	-37	-29	32	41	26	23	19	9
	LE	-56	-55	-93	-71	-95	-79	-64	-52
	A	-32	-57	30	10	36	22	16	14
	Cover & % Area	Open			Open			Open	
Tank #2	Rn	459	480	412	402	435	414	416	422
	G	27	-44	78	-53	14	69	-116	-55
	LE	-462	-434	-517	-371	-519	-467	-352	-362
	A	-24	-2	27	22	70	-16	52	-5
	Cover & % Area	Styrofoam	(80%)	Styrofoam		(51%)	Styrofoam		(76%-1 hole)
Tank #3	Rn	85	77	184	173	197	81	81	84
	G	-18	-8	62	36	37	28	15	-11
	LE	-86	-112	-312	-204	-291	-132	-118	-76
	A	19	43	66	-5	57	23	22	3
	Cover & % Area			Styrofoam		(26%)	Styrofoam		(76%-12 hole)
Tank #4	Rn			298	290	325	81	81	84
	G			67	9	18	30	10	-8
	LE			-448	-317	-423	-146	-132	-96
	A			83	18	80	35	41	20
	Ua (cm/sec)	108	124	111	97	148	115	75	88

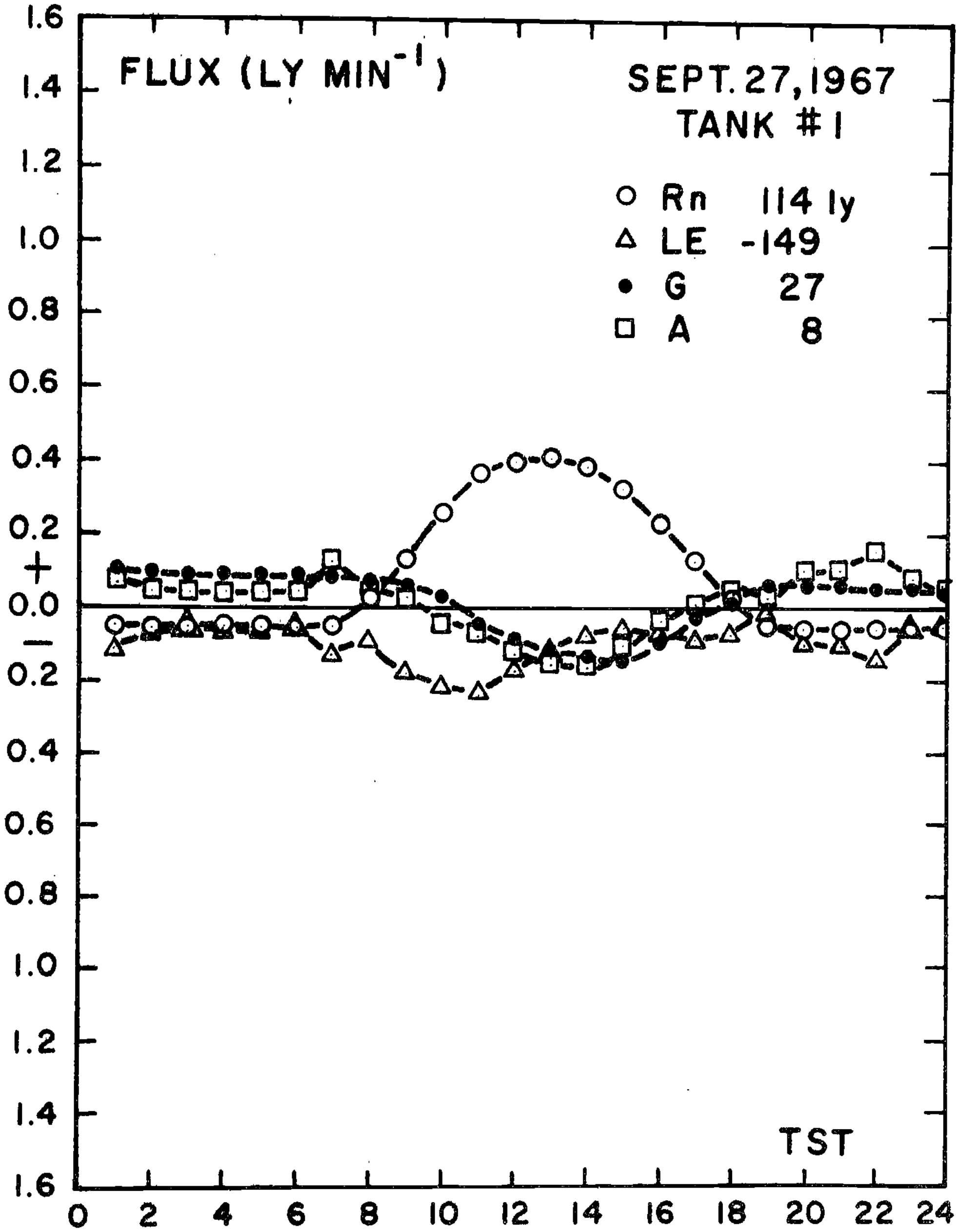

Figure 6.--Hourly distribution of the energy balance components over an insulated evaporation pan with 78 percent cover of foamed wax blocks.

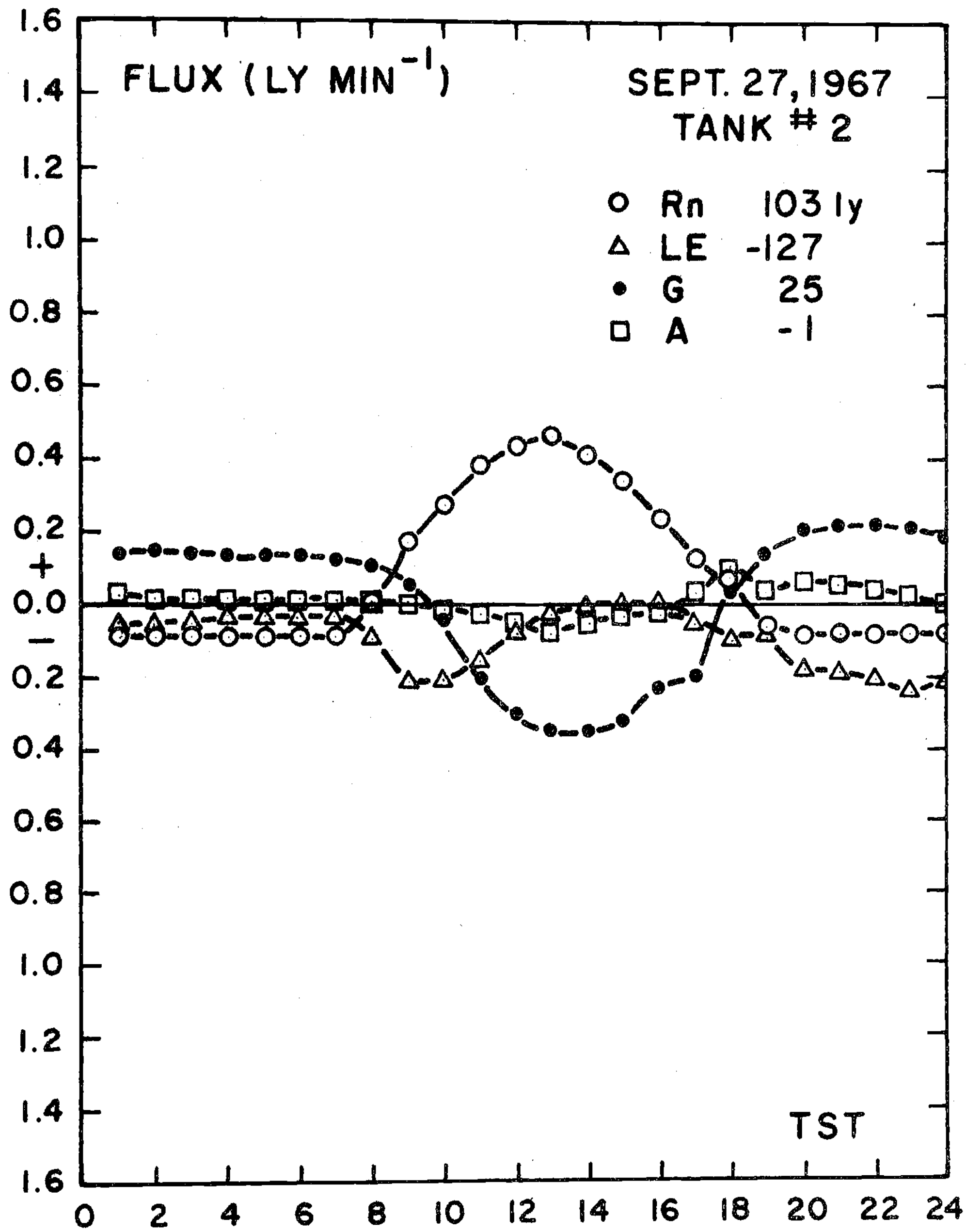

Figure 7.--Hourly distribution of the energy balance components over an insulated evaporation pan with 86 percent cover of white butyl rubber.

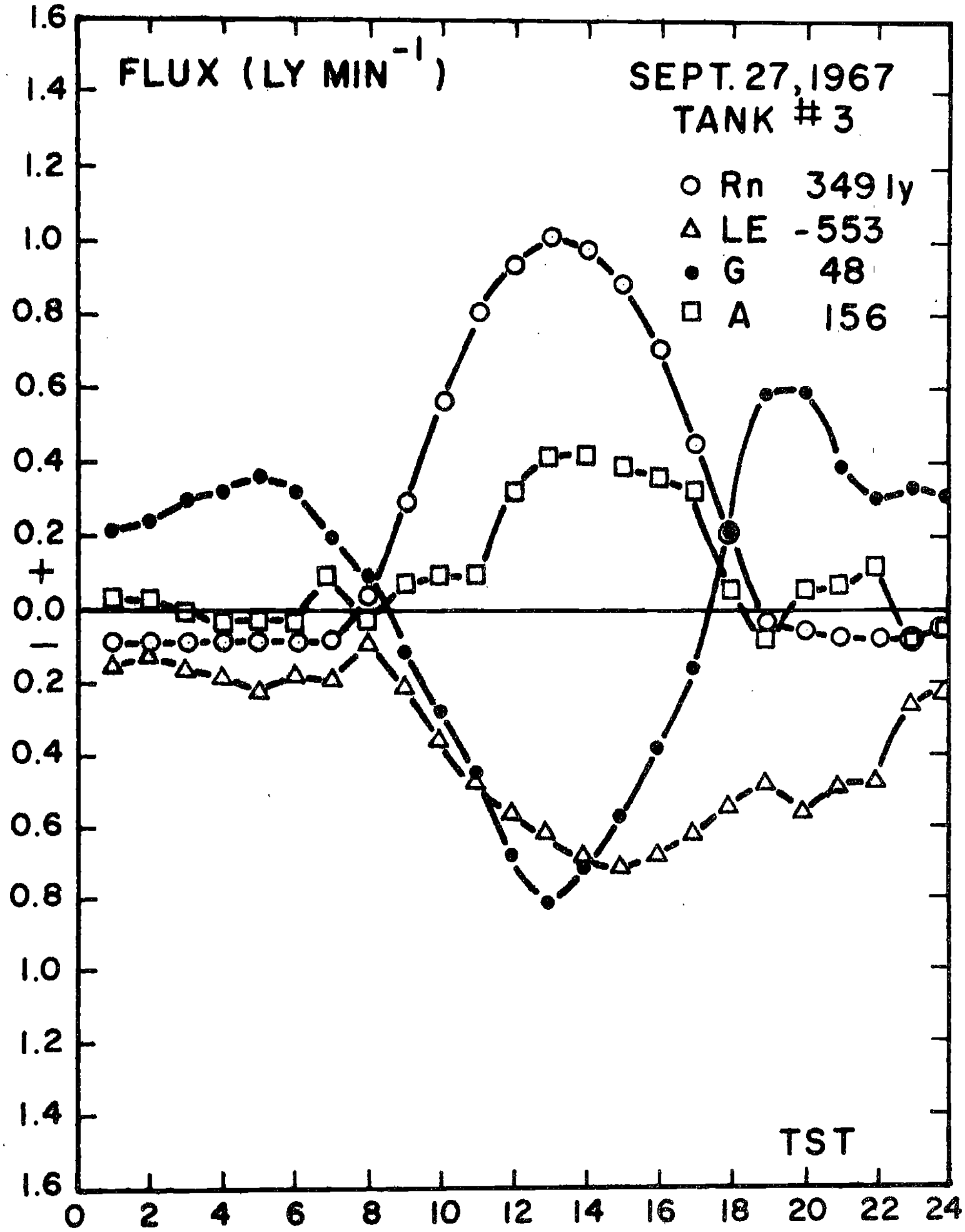

Figure 8.--Hourly distribution of the energy balance components over an insulated evaporation pan without surface cover.

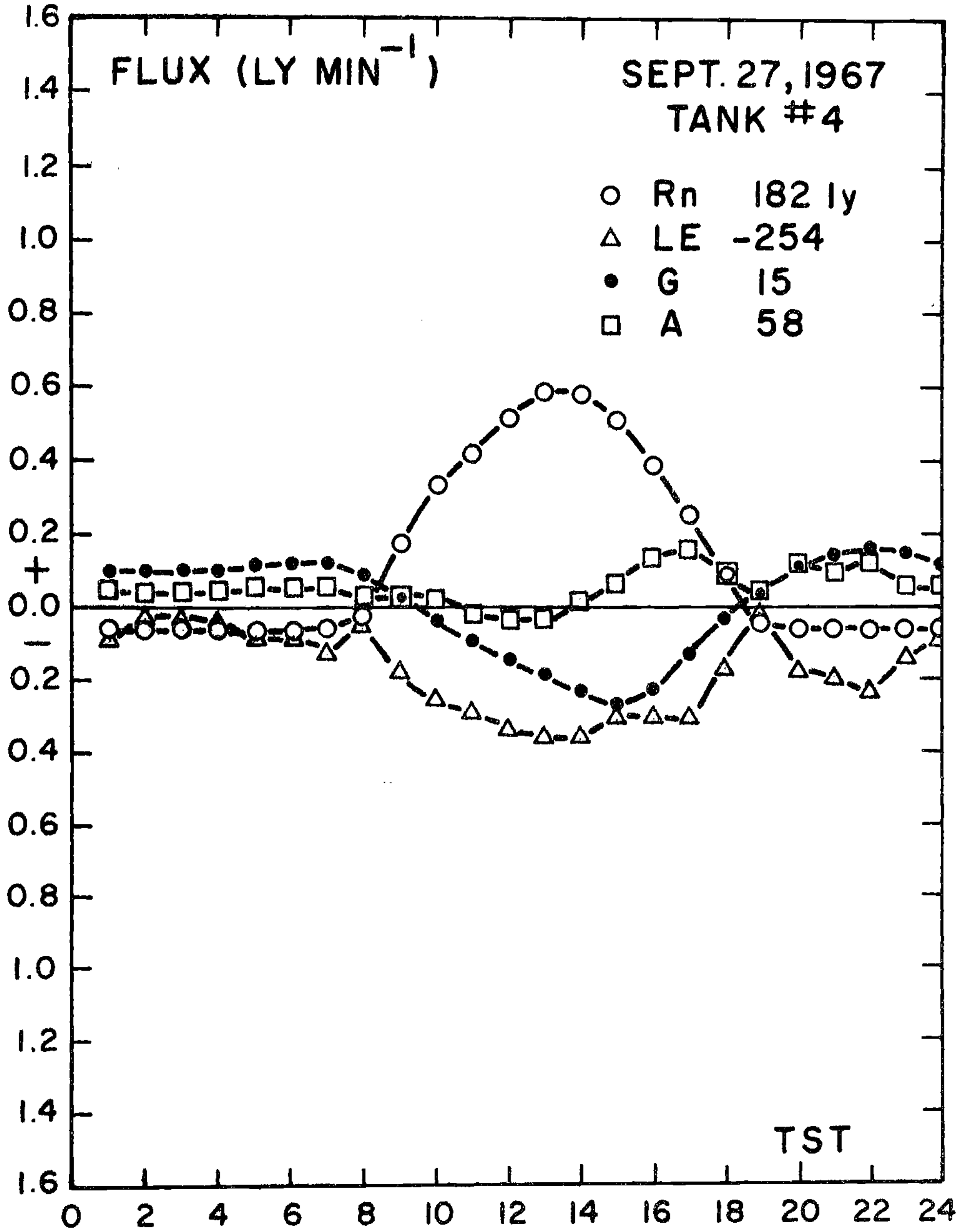

Figure 9.--Hourly distribution of the energy balance components over an insulated evaporation pan with 78 percent cover of lightweight concrete blocks.

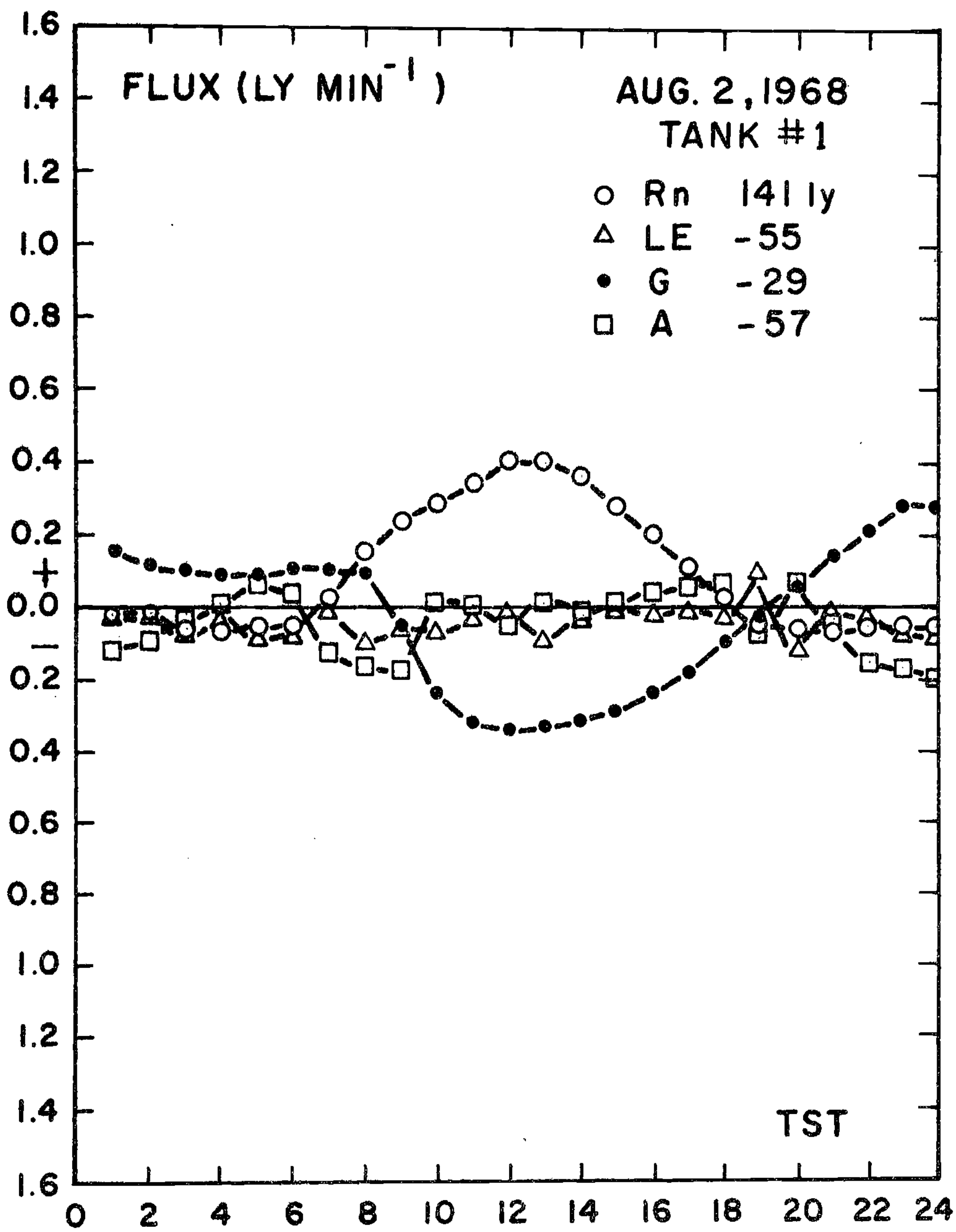

Figure 10.--Hourly distribution of the energy balance components over an insulated evaporation pan with 86 percent cover of white butyl rubber.

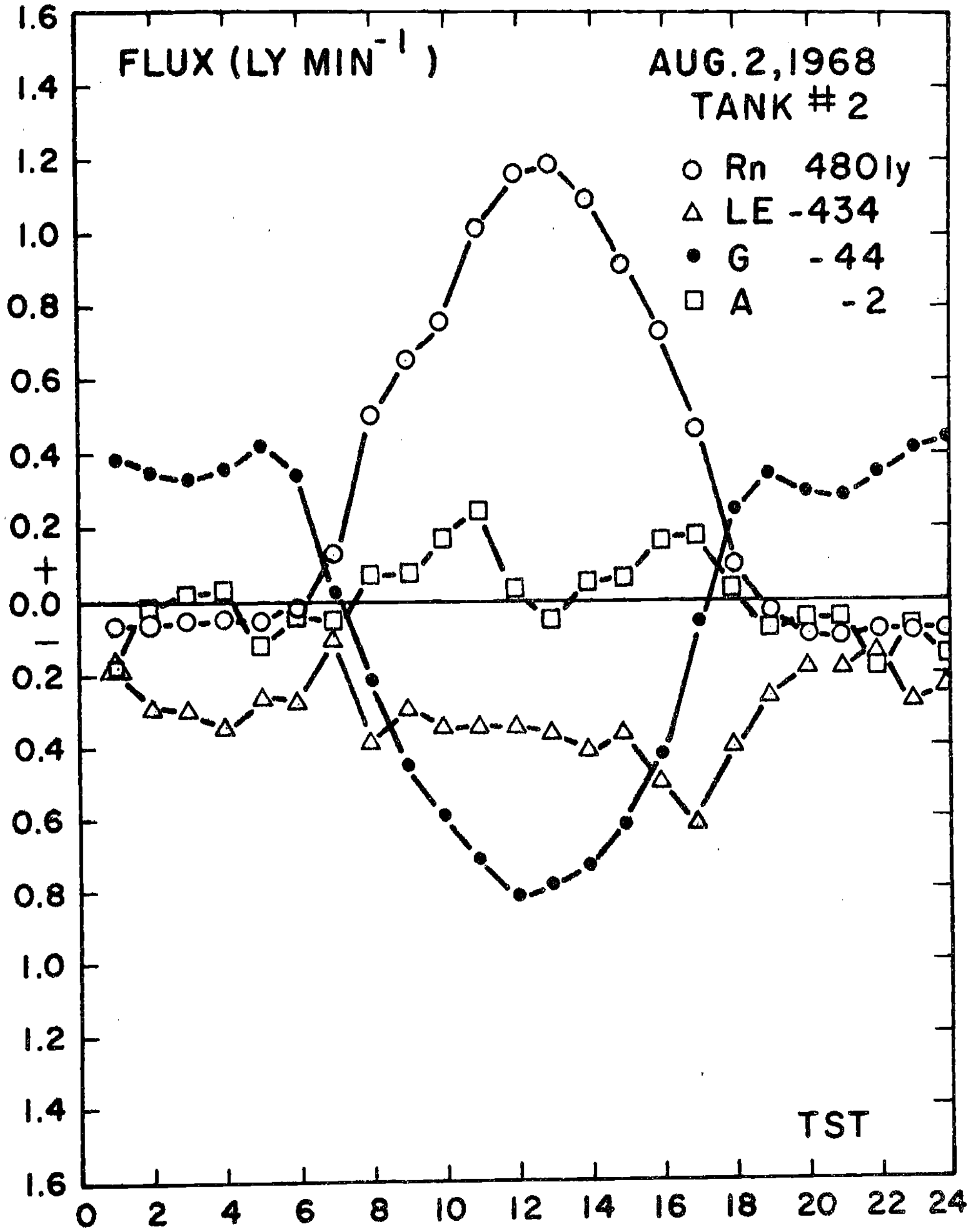

Figure 11.--Hourly distribution of the energy balance components over an insulated evaporation pan without surface cover.

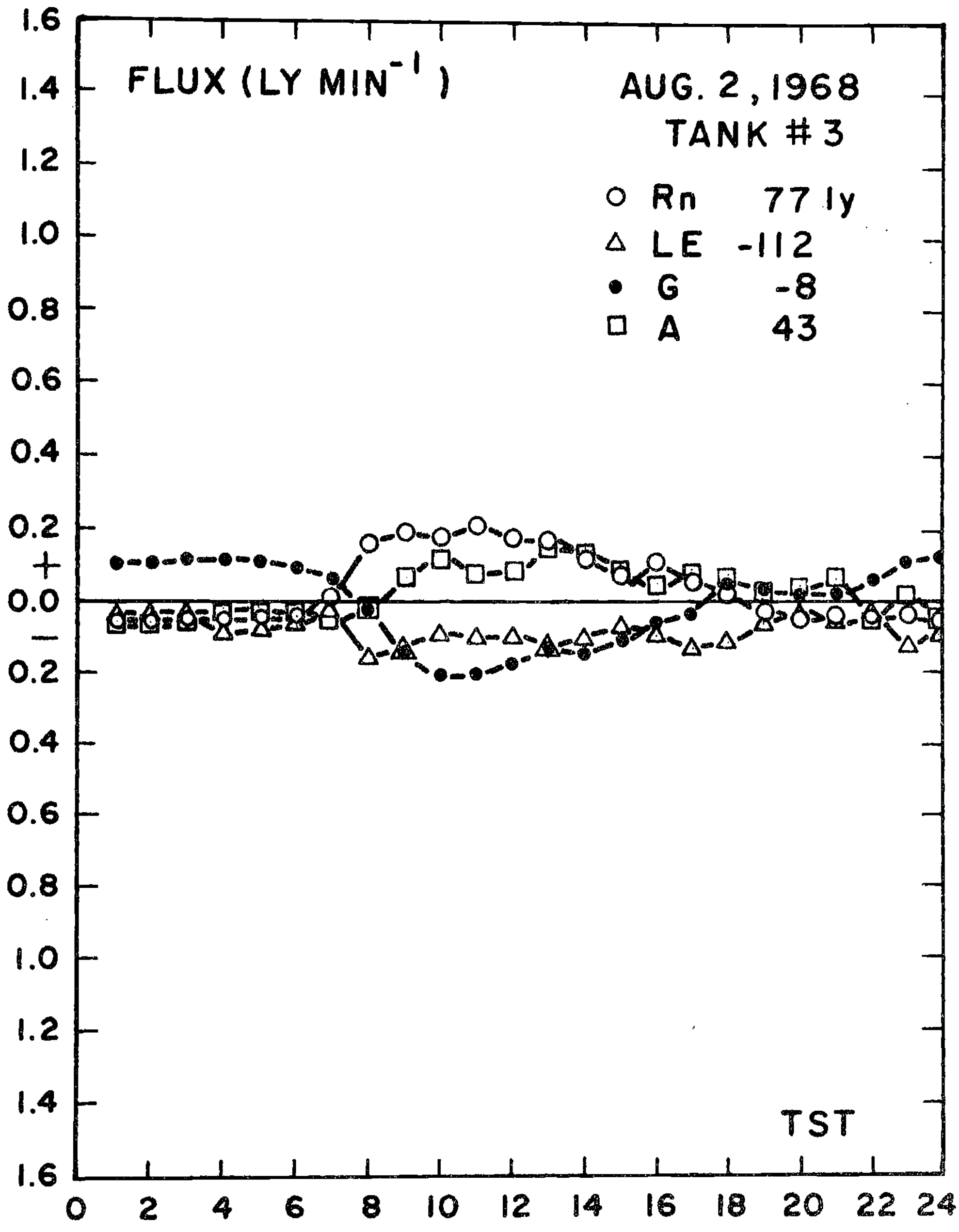

Figure 12.--Hourly distribution of the energy balance components over an insulated evaporation pan with 80 percent cover of styrofoam.

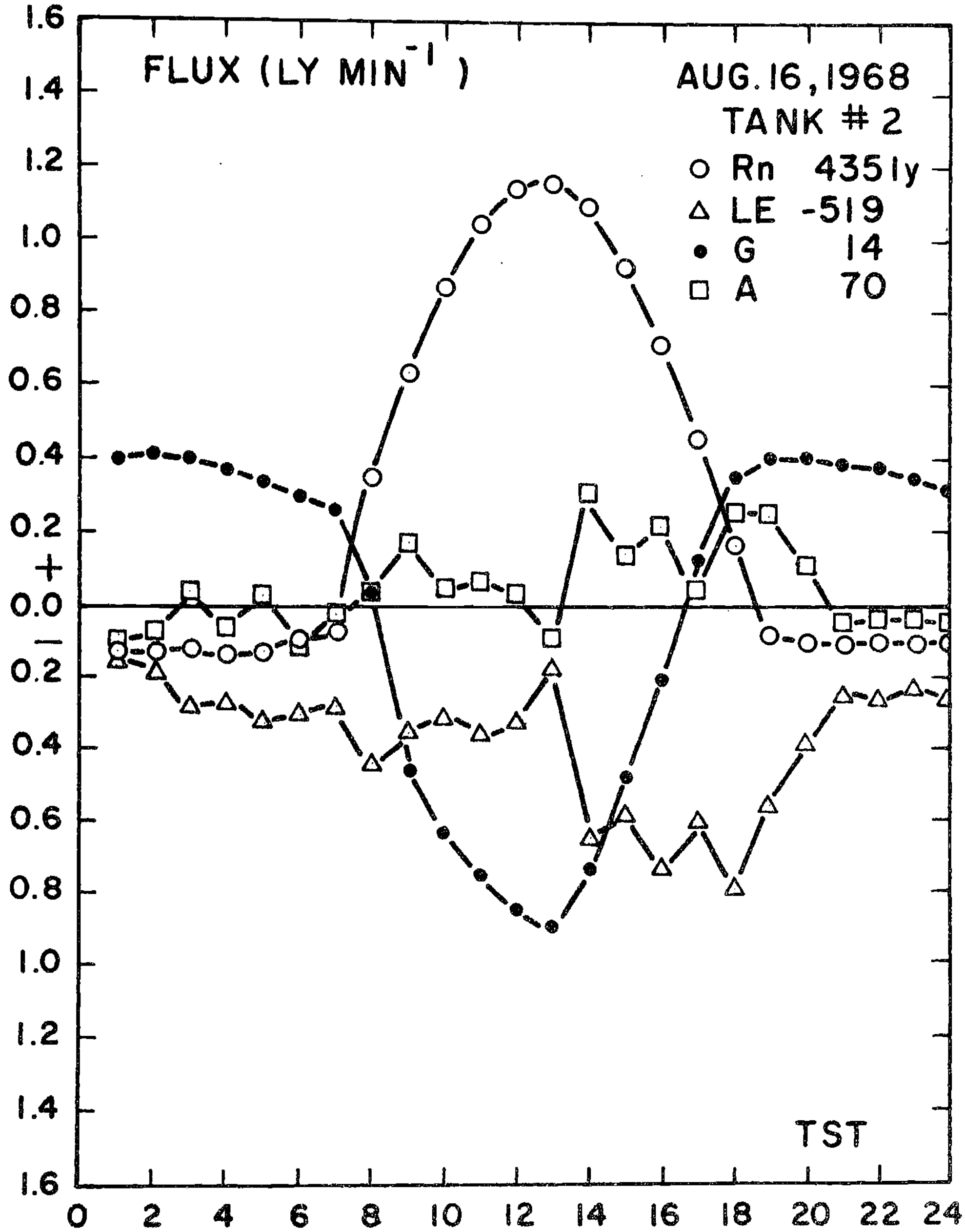

Figure 13.--Hourly distribution of the energy balance components over an insulated evaporation pan without surface cover.

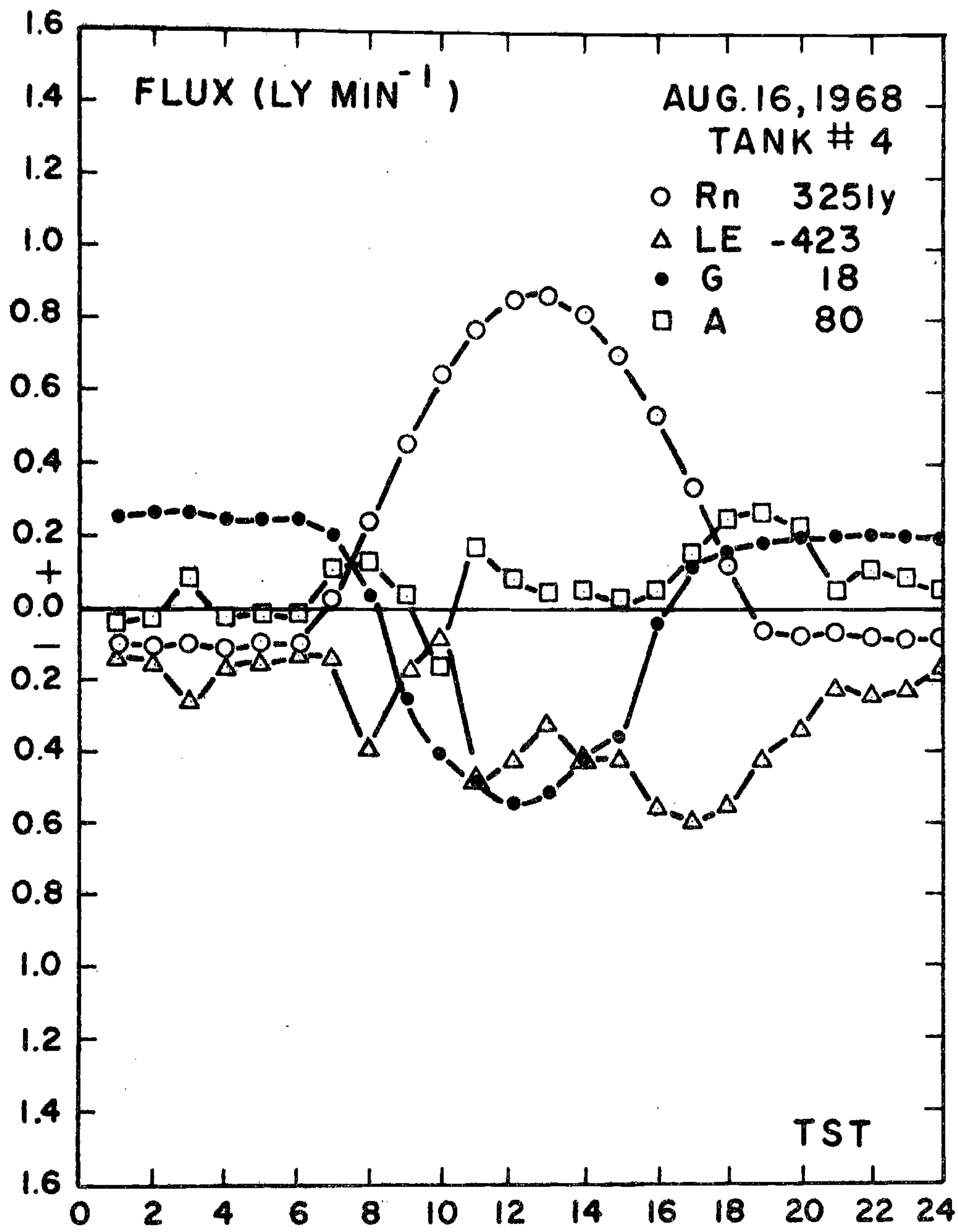

Figure 14.--Hourly distribution of the energy balance components over an insulated evaporation pan with 26 percent cover of styrofoam.

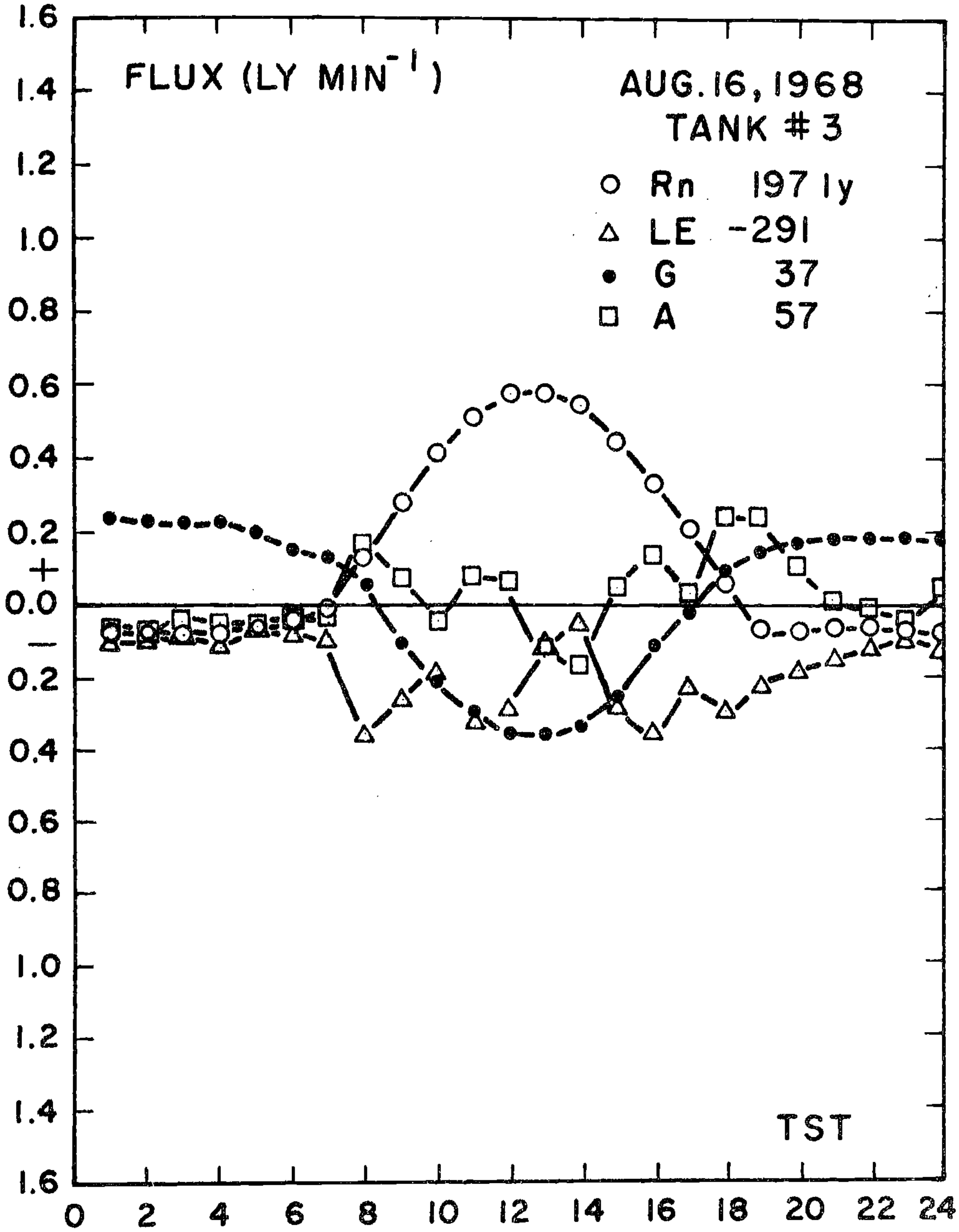

Figure 15.--Hourly distribution of the energy balance components over an insulated evaporation pan with 51 percent cover of styrofoam.

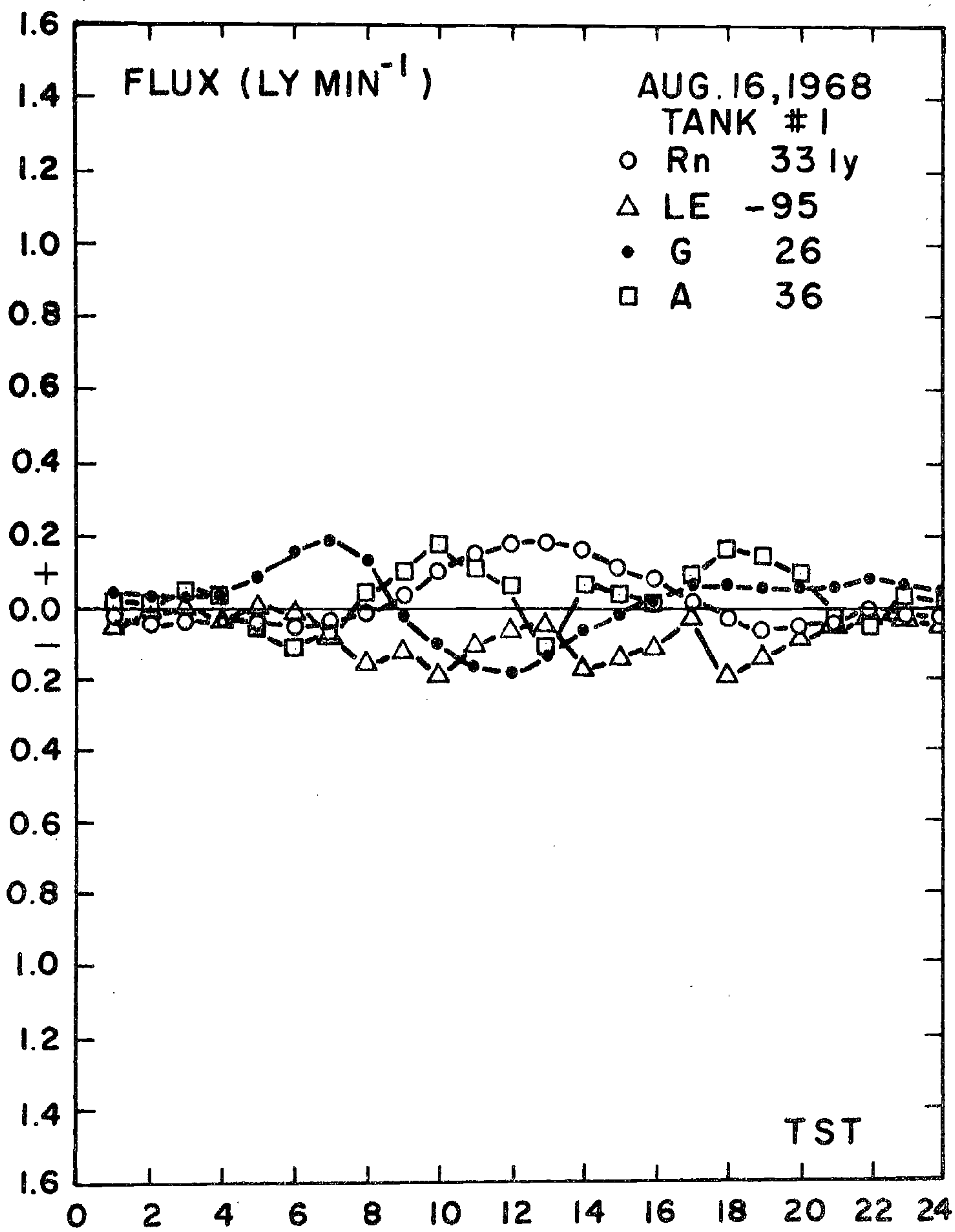

Figure 16.--Hourly distribution of the energy balance components over an insulated evaporation pan with 87 percent cover of styrofoam.

In Figures 6 and 7 the daily totals for all the parameters are of corresponding magnitude. However, the variation in the energy stored in the water is considerably different. They butyl cover, being very thin, allows heat to pass through during the day, thus increasing the energy stored in the water. At night, heat is transferred back through the cover, decreasing the energy stored in the water. The cover of wax blocks, on the other hand, allows very little heat transfer; thus, variation of energy stored in the water is small.

In Figures 8 and 9 the variations are shown for the open tank and concrete block cover, respectively. The variations as shown in Figure 9 for the lightweight concrete blocks are seen to be about midway between those observed on the open tank and the tank with wax blocks as a cover. The heat storage in the open tank varies considerably since radiation penetrates into the water and warms a deeper layer. Also, back radiation at night is not restricted by a cover.

Comparison of variations for styrofoam and butyl, shown in Figures 10 and 12, respectively, indicate that the styrofoam cover dampens the variation of all parameters considerably, although there is still a slight peak near midday. In this particular case, evaporation from the tank with the butyl cover is minimum during midday, indicating that the radiative energy is being stored in the water. The other two tanks show maximum evaporation at midday under the same atmospheric conditions. Variations on the open tank are presented in Figure 11 for comparative purposes.

Figures 13 through 16 present the variations as determined for August 16, 1968. In this case the effects of three styrofoam covers of different sizes are compared to the open tank. The areas covered in Figure 14, 15, and 16 were 26, 51, and 87 percent, respectively. These graphs present a vivid display of the dampening effect of this type of cover. The magnitude of variations are seen to be inversely proportional to the area covered.

The effect of these covers on average water temperatures may be an important design consideration. The amplitude of the variation of energy stored in the water, as shown in Figure 16, indicates a nearly constant average temperature (with a range of less than $1^{\circ}C$ in this case), whereas the average temperature within the open tank, as indicated by variation of stored energy, may vary by several degrees ($5^{\circ}C$ in this case). This change in temperature regime may limit the species of plants and animals that could adapt to these conditions.

Relationship of Cover Properties to Evaporation Reduction. In an attempt to relate the amount of evaporation reduction to some physical property of the covers, it was noted that the percent of evaporation reduction was almost the same as the percent of net radiation reduction. Table 12 shows the percent of reduction in net radiation and evaporation as compared to that measured over the open tank. For evaporation, both calculated and measured values compared to values of net radiation reduction, are presented. These comparisons also give an indication of the validity of the calculations of evaporation by the modified combination method.

Table 12

Reduction in Net Radiation Compared to Evaporation Reduction

Period, Material, and percent coverage	Percent Reduction in Net Radiation As Compared to Open Tank	Percent Reduction in Evaporation as Compared to Open Tank	
		Measured	Calculated
23-30 Sep 1967			
Wax (78%)	72	74	73
White Butyl (86%)	70	79	79
Concrete (78%)	50	55	53
18-20 Oct 1967			
Wax (78%)	77	73	69
White Butyl (86%)	76	84	82
Styrofoam (80%)	92	76	69
1-2 Aug 1968			
White Butyl (86%)	72	88	84
Styrofoam (80%)	83	78	83
14-16 Aug 1968			
Styrofoam (87%)	93	82	82
Styrofoam (51%)	56	43	30
Styrofoam (26%)	27	16	10
22-24 Aug 1968			
Styrofoam (87%)	93	83	83
Styrofoam (76%-1 Hole)	80	72	70
Styrofoam (76%-12 Hole)	80	68	64

A comparison of measured evaporation reduction and measured net radiation reduction is presented in Figure 17 in order to emphasize this relationship. Regression analysis of the data pertaining to the styrofoam covers produces a correlation coefficient of 0.99. In other words, there is a very close correlation between the reduction in net radiation and evaporation reduction as compared to an open tank. Regression analysis was not undertaken for the other cover materials because of lack of data. However, the available data are shown in Figure 17 for comparative purposes. These data show that for the same percentage of reduction in net radiation, the other materials reduced evaporation more than styrofoam. The thin white butyl cover would appear to be the most efficient of any material tested. The plots of hourly distribution of the energy balance equation components indicated that the butyl may be more efficient, but were not sufficient themselves to warrant this conclusion.

The close correlation between evaporation reduction and reduction in net radiation also points out that in designing covers to reduce evaporation, emphasis should be aimed at increasing the reflectance and emittance of the cover material. For example, changing the roughness would be of minor importance compared to reflective characteristics.

The percent of surface area covered was also found to correlate with evaporation reduction. This relationship is presented in Figure 18.

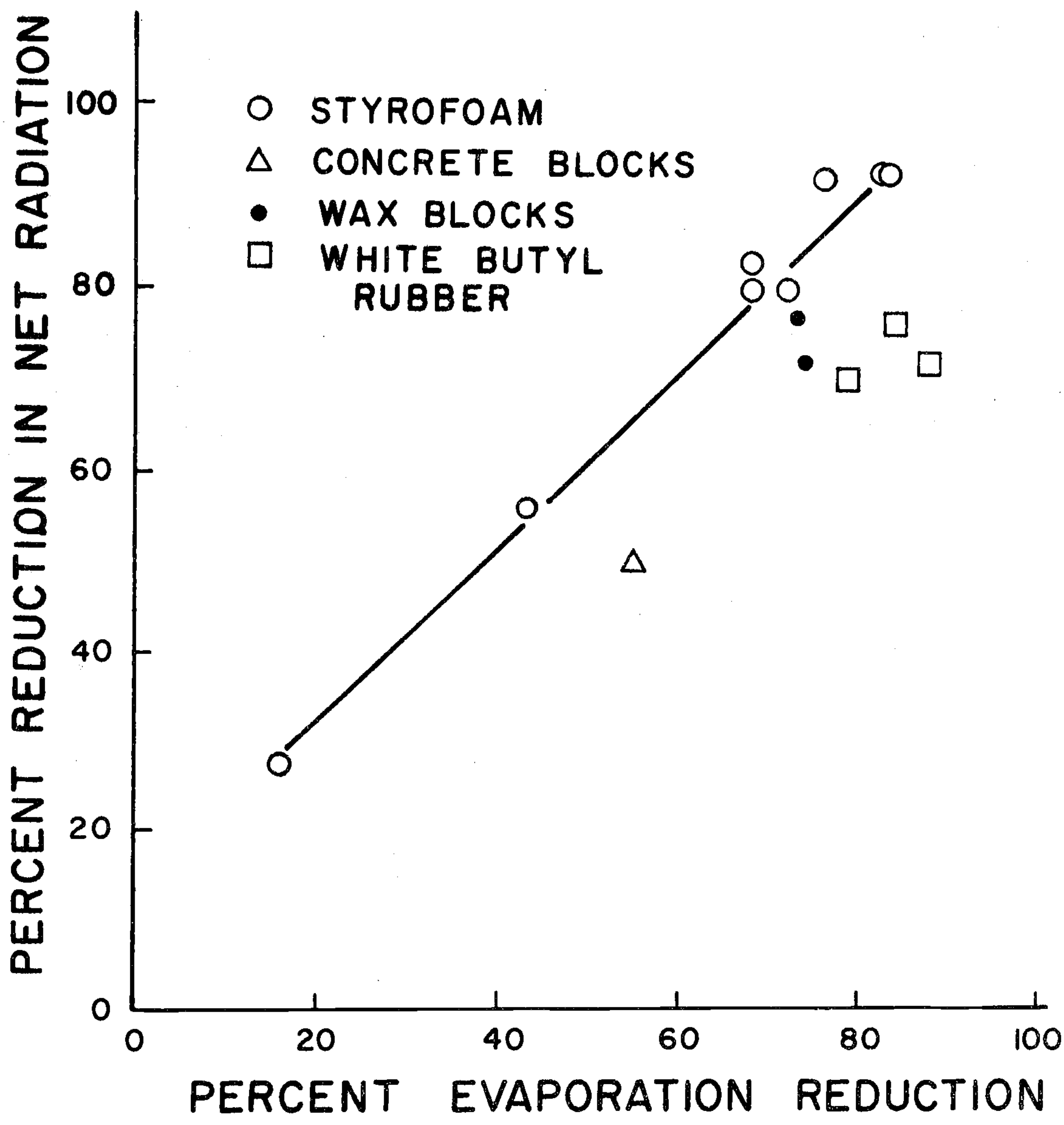

Figure 17.--Relationship between evaporation reduction and reduction in net radiation.

These data are presented in Table 13 of the following section. Regression analysis of the data pertaining to styrofoam covers produced a correlation coefficient of 0.99. This close correlation would probably be found for each cover material tested, however, the slope of the best fit line may be considerably different as suggested by the data point for concrete blocks.

According to Figure 18, the materials are about equally efficient, except for the concrete blocks, which reduce evaporation less than the others for the same area covered. Since Figure 17 indicated the concrete blocks would be more efficient than the styrofoam, if the reduction in net radiation were the same, this difference must be due to lower albedo of the concrete blocks.

While studying various types of hexadecanols for use in reducing evaporation, Lauritzen (1967) experimented with a black foamed polyethylene. Although his tests were conducted on small laboratory dishes and may not represent field conditions as far as absolute values are concerned, he did note a correlation between area covered and evaporation reduction. The four values he reported are presented in Figure 18. The correlation coefficient was again 0.99. These data are presented for comparison purposes only and undoubtedly would be different under field conditions where radiative effects were present.

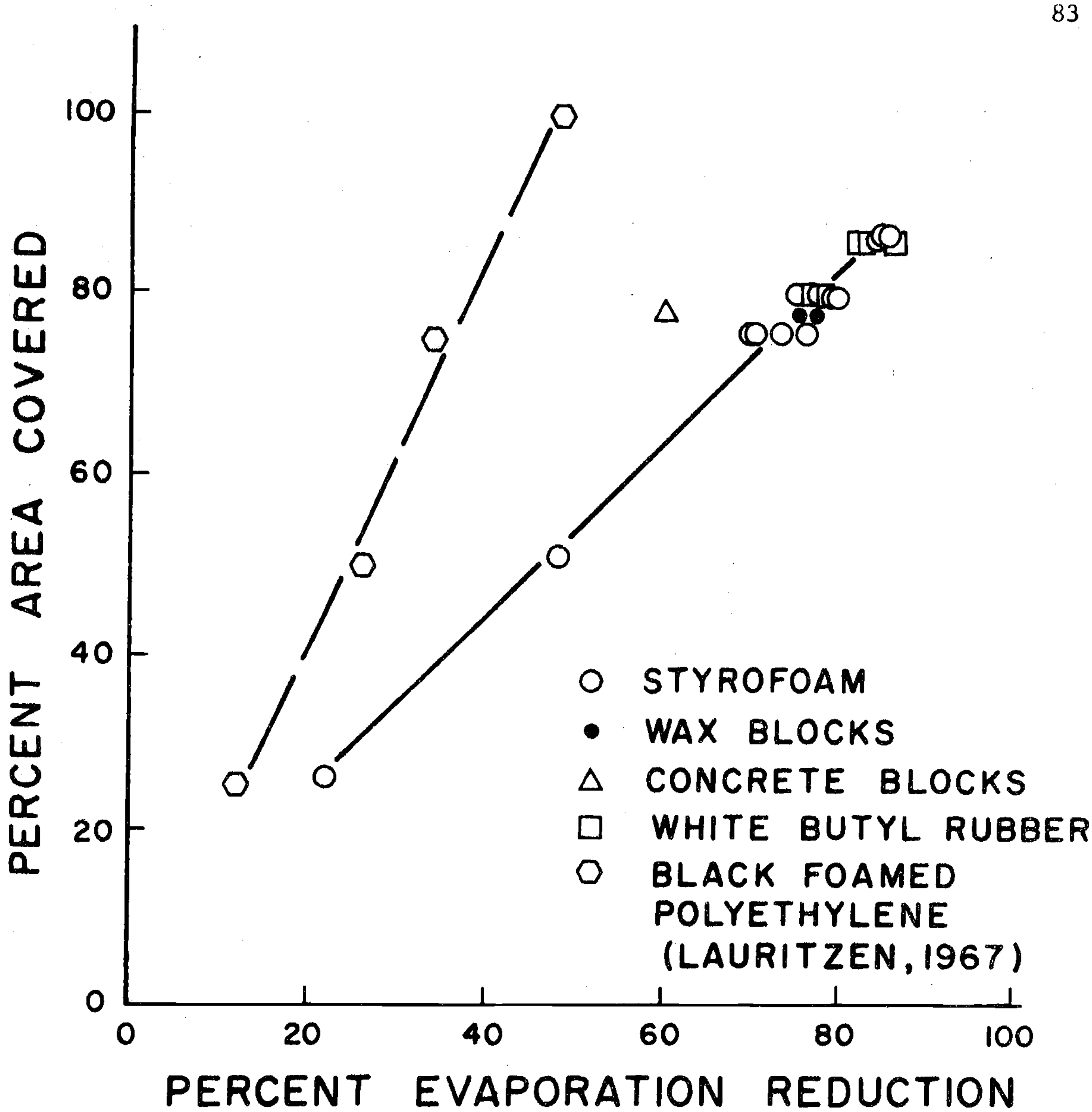

Figure 18.--Relationship between evaporation reduction and percent of surface covered.

Efficiencies of Covers Tested. Evaporation measurements recorded during this study are presented in Table 13. Also shown are the percent of surface area covered and the percent of evaporation reduction as compared to the open tank. The measurements cover a longer period than the energy balance results presented in Tables 10 and 11, since only data on selected days were used in those calculations. Figure 18, which was derived from the same data, shows that for these covers, all of which were white or light colored, evaporation reduction was essentially equal to the precent of surface area covered. It should also be noted that all of these covers were impermeable except for the lightweight concrete blocks, which allowed some transfer of moisture.

An interesting point noted was that the styrofoam cover with 1 hole was more efficient than the one with 12 holes, although both were the same color and covered the same area. In order to eliminate any effect of exposure, the covers were alternated on August 29, and evaporation was again recorded. Exchanging the covers had no effect on the results obtained for the 12-hole cover, and only slightly affected results for the 1-hole cover. The cover with 1 hole was still the more efficient. From the measurements available, it was not possible to determine the cause of this difference. It could have been due to a difference in roughness or to reduced air transfer and turbulence within the smaller holes.

Table 13

Efficiency of floating materials in reducing evaporation

Cover / Period	Evap (cm)	Evap (cm)	Red %	Area %	Evap (cm)	Red %	Area %	Evap (cm)	Red %	Area %
	Open	Foamed Wax			Concrete blocks			Butyl rubber		
11 Sep - 2 Oct 67	-11.36	-2.84	75	78	-4.50	60	78	-2.21	81	86
	Open	Foamed Wax			Styrofoam			Butyl rubber		
4 Oct - 7 Nov 67	-15.45	-3.56	77	78	-3.45	78	80	-2.74	82	86
22 Jul - 3 Aug 68	- 4.98				-1.17	76	80	- .74	85	86
17 Sep - 1 Oct 68	- 6.84				-1.75	74	80	-1.66	76	80
11 Oct - 18 Oct 68	- 2.69				- .56	79	80	- .66	75	80
	Open	Styrofoam			Styrofoam			Styrofoam		
10 Aug - 19 Aug 68	- 6.37	-1.05	84	87	-3.31	48	51	-4.96	22	26
	Open	Styfofoam			Styrofoam - 1 hole			Styrofoam - 12 hole		
19 Aug - 29 Aug 68	- 5.58	- .92	84	87	-1.35	76	76	-1.67	70	76
29 Aug - 10 Sep 68	- 6.97	-1.16	83	86	-1.87	73	76	-2.12	70	76

CONCLUSIONS

The following conclusions are based on: a theoretical analysis of the energy balance equation as it applies to a partially covered body of water; and experimental analysis of the energy balance for partially-covered insulated evaporation tanks.

The conclusions are:

1. The most important properties to consider in the design of floating materials for reducing evaporation are reflectance and emittance.

2. Covers should be colored white.

3. The combination method of determining evaporation from an open water surface proved best for use under the conditions of this study.

4. The modified combination method of determining evaporation from a partially covered water surface is valid as derived in this study.

5. The use of insulated evaporation tanks provides an easy and accurate method of determining long-wave radiation from the atmosphere, and net radiation over other surfaces where reflectance is known.

6. For the covers tested in this study, the reduction in net radiation, occurring due to covering part of the surface, is highly correlated with the reduction in evaporation from that surface as compared to an open water surface.

7. For styrofoam covers of the type used in this study, the percent of evaporation reduction occurring due to placing a cover on the surface is highly correlated to the percent of area covered.

8. For all of the covers tested, the percent of evaporation reduction was almost the same as the area covered.

9. The styrofoam cover with 1 hole was more efficient than the one with 12 holes, although both were the same color and covered the same area.

It is believed that this study has provided important information to consider in the design of floating covers to reduce evaporation, as well as providing considerable insight into a relatively untouched subject of evaporation from partially covered bodies of water.

APPENDIX Table 14

Meteorological Data

	20 September 1967						21 September 1967						22 September 1967					
				Open Tank						Open Tank						Open Tank		
Time	U	T_a	e_a	R_n	T_w	Tavg	U	T_a	e_a	R_n	T_w	Tavg	U	T_a	e_a	R_n	T_w	Tavg
1	43	21.1	11	-.10	20.3	23.1	47	24.8	14	-.08	23.1	25.0	55	27.7	17	-.07	25.3	26.4
2	47	20.1	11	-.10	20.1	22.8	70	24.0	14	-.09	23.3	24.8	51	25.3	16	-.08	24.0	26.1
3	38	17.8	12	-.10	20.8	22.5	41	23.3	15	-.09	22.8	24.6	78	24.0	17	-.07	23.1	25.7
4	81	17.8	10	-.09	20.3	22.2	40	23.3	15	-.08	23.1	24.3	43	25.0	16	-.04	22.8	25.4
5	27	17.8	10	-.10	19.3	21.9	91	22.3	16	-.08	22.1	24.0	48	24.0	16	-.03	24.3	25.1
6	22	17.6	11	-.10	19.1	21.7	31	20.8	16	-.09	22.1	23.7	51	23.5	17	-.06	23.1	24.9
7	51	18.3	11	-.07	19.8	21.4	29	19.8	16	-.09	22.1	23.5	55	22.3	17	-.08	23.8	24.8
8	130	18.6	12	.07	19.8	21.2	30	22.1	17	.10	23.8	23.4	88	23.1	17	.05	23.8	24.8
9	152	21.6	12	.28	19.3	21.1	67	24.5	18	.31	22.3	23.5	136	28.2	17	.28	25.5	24.9
10	112	24.8	12	.56	19.3	21.4	60	27.7	17	.58	23.8	23.8	207	30.6	16	.56	26.0	25.2
11	129	27.7	13	.73	20.8	22.1	125	29.7	17	.77	24.0	24.3	339	33.3	14	.78	27.7	25.7
12	121	31.1	13	.89	22.6	22.9	147	31.1	17	.94	25.0	25.0	401	34.5	16	.93	28.2	26.2
13	119	31.8	13	1.00	22.8	23.7	107	32.6	17	1.01	25.8	26.0	329	35.7	16	1.01	29.2	26.7
14	136	33.1	13	1.01	24.0	24.5	100	34.2	18	1.00	26.5	26.9	336	36.6	15	.99	29.7	27.2
15	113	33.5	13	.87	24.5	25.4	95	36.2	17	.88	27.5	27.7	233	37.1	15	.86	30.2	27.7
16	113	34.0	13	.75	25.3	26.1	166	37.4	16	.72	29.4	28.5	237	38.3	15	.83	30.9	28.0
17	73	35.5	13	.50	25.0	26.5	147	37.4	16	.50	29.7	28.9	188	36.6	17	.64	29.9	28.2
18	54	34.2	13	.20	24.8	26.7	152	36.6	17	.20	29.4	28.9	228	36.0	16	.25	29.4	28.3
19	49	32.1	16	-.04	25.0	26.6	226	34.2	17	-.01	27.5	28.3	221	34.2	16	-.00	28.2	28.2
20	46	29.9	15	-.08	24.3	26.5	162	31.8	16	-.04	26.7	27.8	118	32.3	17	-.04	27.2	28.0
21	21	27.7	15	-.08	24.0	26.3	47	30.9	17	-.04	25.3	27.4	141	31.8	16	-.04	26.7	27.6
22	41	26.0	13	-.09	23.8	26.0	56	30.4	17	-.02	25.8	27.1	84	29.7	15	-.03	26.2	27.2
23	67	24.8	13	-.08	23.8	25.6	113	28.7	17	-.07	25.8	26.8	84	28.2	15	-.03	25.8	26.8
24	89	24.0	14	-.08	22.6	25.2	79	27.5	17	-.07	25.0	26.6	103	25.8	18	-.07	25.0	26.4
Avg	78	25.9	13	-	22.1	23.9	93	28.8	16	-	25.1	25.9	161	30.2	16	-	26.5	26.5

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

September 23, 1967

					Wax Blocks (78%)				White Butyl (86%)				Concrete Blks (78%)				Open Tank		
Time	U	T_a	e_a	S	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	Tavg
1	58	27.2	16	0	-.01	20.5	20.8	24.5	-.04	23.3	25.7	24.3	-.02	23.3	23.2	24.4	-.03	25.0	26.0
2	76	24.8	15	0	-.04	20.6	19.9	24.4	-.08	22.8	25.0	24.2	-.05	22.3	22.1	24.3	-.08	24.3	25.7
3	39	23.5	17	0	-.03	20.5	19.0	24.3	-.07	22.6	24.4	24.0	-.04	23.1	21.1	24.1	-.07	23.5	25.3
4	39	23.5	16	0	-.02	20.0	18.2	24.3	-.05	22.3	23.9	23.8	-.03	22.6	20.4	24.0	-.04	24.3	25.0
5	36	22.1	18	0	-.04	20.1	17.4	24.2	-.08	22.1	23.5	23.7	-.05	21.1	19.9	23.9	-.08	24.3	24.7
6	52	21.1	19	0	-.05	19.8	16.7	24.1	-.08	21.8	23.2	23.6	-.05	21.6	19.9	23.8	-.09	22.3	24.6
7	65	19.8	19	0	-.05	19.5	16.3	24.0	-.09	22.1	23.1	23.6	-.05	21.6	20.2	23.7	-.09	21.6	24.4
8	69	21.3	19	.14	.02	19.0	20.1	23.9	-.01	22.1	23.4	23.5	-.01	21.8	21.3	23.6	.04	22.3	24.4
9	115	24.8	18	.42	.11	20.4	25.8	23.9	.18	22.1	26.3	23.4	.17	22.1	24.0	23.6	.27	23.1	24.6
10	160	28.2	18	.68	.20	22.0	31.8	24.0	.31	23.3	30.5	23.5	.33	23.1	29.2	23.7	.57	24.5	24.9
11	163	31.1	19	.90	.30	23.1	37.0	24.2	.41	25.8	35.1	23.9	.41	25.0	33.8	23.9	.78	26.0	25.3
12	201	34.2	18	1.05	.35	23.7	40.8	24.4	.49	27.5	39.0	24.2	.52	25.0	36.6	24.1	.96	27.7	26.1
13	318	36.2	16	1.12	.41	23.7	43.1	24.6	.50	27.7	41.4	24.5	.55	24.3	38.2	24.5	1.02	28.9	27.0
14	348	36.9	15	1.14	.39	23.2	44.2	24.7	.45	29.4	42.7	25.1	.55	24.5	39.1	24.8	1.01	29.9	27.8
15	291	37.1	14	1.06	.35	22.7	44.3	24.8	.41	29.9	42.8	25.4	.50	24.5	39.0	24.9	.94	30.2	28.2
16	284	37.1	14	.88	.26	21.9	43.0	24.9	.31	30.2	41.5	25.7	.39	24.8	37.9	25.0	.75	30.7	28.6
17	254	36.4	15	.63	.16	20.9	39.7	24.9	.18	29.2	37.2	25.9	.25	23.5	35.0	25.2	.50	30.9	28.7
18	219	34.7	14	.09	-.04	20.1	33.8	24.9	-.07	27.0	32.4	25.5	-.03	23.1	29.6	25.1	.01	30.2	28.5
19	96	31.8	16	.04	-.04	19.7	29.6	24.9	-.08	25.8	30.1	25.6	-.04	22.6	26.9	25.1	-.04	28.2	28.3
20	75	32.3	14	0	-.02	19.4	27.4	24.9	-.04	25.3	28.8	25.8	-.02	23.8	26.1	25.1	-.02	27.0	28.0
21	124	32.1	12	0	-.05	19.3	25.7	24.9	-.07	24.5	27.9	25.6	-.05	23.3	25.5	25.0	-.02	27.0	27.7
22	79	30.2	13	0	-.03	19.3	24.2	24.8	-.06	24.0	27.2	25.3	-.04	23.3	24.8	25.0	-.06	26.2	27.3
23	64	29.7	13	0	-.02	19.4	23.0	24.8	-.04	24.0	26.5	25.3	-.02	23.3	24.0	24.8	-.05	25.3	26.8
24	64	26.5	13	0	-.05	19.7	21.8	24.7	-.08	23.8	26.1	25.0	-.05	22.8	22.9	24.7	-.03	25.0	26.3
Avg	137	29.3	16			20.8	28.5	24.5		24.9	30.3	24.6		23.2	27.5	24.4		26.2	26.4

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

September 27, 1967

Time	U	T_a	e_a	S	Wax Blocks (78%) R_n	T_w	T_c	Tavg	White Butyl (86%) R_n	T_w	T_c	Tavg	Concrete Blks (78%) R_n	T_w	T_c	Tavg	Open Tank R_n	T_w	Tavg
1	123	21.8	14	0	-.06	19.8	17.0	23.6	-.10	21.1	22.5	23.2	-.06	21.3	19.7	23.6	-.10	20.3	24.2
2	79	21.0	14	0	-.06	20.0	16.5	23.5	-.09	20.8	22.2	23.2	-.07	21.3	19.2	23.4	-.10	21.5	24.5
3	58	20.1	14	0	-.06	19.8	15.9	23.3	-.09	20.8	21.9	23.0	-.07	21.3	18.8	23.4	-.10	21.8	24.2
4	79	19.8	14	0	-.06	19.6	15.7	23.2	-.09	20.3	21.7	22.9	-.07	21.6	18.5	23.3	-.09	21.6	23.9
5	84	19.8	14	0	-.06	19.1	15.5	23.2	-.09	20.1	21.5	22.8	-.06	21.3	18.3	23.2	-.09	21.3	23.5
6	73	19.8	14	0	-.06	19.3	15.4	23.1	-.09	20.1	21.4	22.6	-.06	21.1	18.3	23.0	-.09	21.1	23.2
7	218	20.0	14	0	-.06	19.1	15.3	23.0	-.09	20.3	21.4	22.5	-.05	20.3	18.4	22.9	-.09	20.5	23.0
8	49	20.9	15	.13	0	19.3	17.3	22.9	0	20.8	22.8	22.4	-.02	21.3	20.2	22.8	.03	23.3	22.9
9	117	25.2	16	.42	.12	20.1	26.2	22.9	.17	20.8	26.4	22.3	.17	22.3	24.4	22.8	.28	24.5	23.0
10	165	27.7	16	.68	.26	20.3	32.7	22.9	.27	21.6	30.4	22.4	.32	23.8	28.7	22.8	.56	25.0	23.3
11	168	29.8	16	.89	.37	20.8	36.8	22.9	.40	23.5	33.8	22.6	.41	24.8	32.3	22.9	.81	25.8	23.8
12	337	31.4	16	1.04	.40	21.1	38.9	23.0	.43	25.8	36.5	23.0	.52	24.8	35.1	23.1	.94	26.7	24.5
13	395	32.4	15	1.12	.41	21.3	40.3	23.1	.46	26.5	37.9	23.4	.57	25.5	35.9	23.2	1.02	27.5	25.4
14	385	33.1	15	1.11	.38	21.3	41.1	23.3	.41	27.0	38.7	23.8	.59	25.8	36.9	23.4	.99	27.7	26.1
15	368	33.7	15	1.02	.33	21.3	41.0	23.4	.34	28.2	38.9	24.1	.51	26.2	34.7	23.7	.89	28.2	26.7
16	326	34.1	14	.85	.24	21.1	40.0	23.5	.24	28.2	38.4	24.4	.39	26.2	32.8	23.9	.70	28.4	27.2
17	300	33.5	14	.60	.14	20.3	37.5	23.5	.12	27.5	36.0	24.5	.25	25.3	30.4	24.0	.45	28.2	27.4
18	124	32.2	14	.33	.03	20.1	32.5	23.5	.01	25.8	31.7	24.5	.10	23.8	27.1	24.0	.21	27.7	27.1
19	30	30.1	14	.03	-.05	19.1	27.8	23.4	-.07	23.8	28.3	24.3	-.05	23.1	24.9	24.0	-.03	25.5	26.5
20	175	28.1	14	0	-.06	19.1	24.6	23.4	-.08	23.1	26.5	24.1	-.05	22.3	23.3	23.9	-.05	24.8	25.9
21	182	26.3	14	0	-.06	19.3	22.1	23.3	-.08	22.3	25.1	23.9	-.06	22.1	22.0	23.7	-.08	23.8	25.4
22	270	24.7	14	0	-.06	19.3	20.0	23.2	-.08	21.8	24.2	23.7	-.06	22.1	20.9	23.5	-.07	22.8	24.9
23	87	23.3	14	0	-.06	19.3	18.0	23.2	-.08	21.6	23.5	23.5	-.06	21.6	20.1	23.4	-.08	22.3	24.6
24	74	22.1	13	0	-.05	19.3	16.5	23.1	-.08	21.1	22.9	23.4	-.06	21.6	19.5	23.2	-.09	22.1	24.3
Avg	178	26.3	14			20.0	26.0	23.2		23.0	28.1	23.4		23.0	25.0	23.4		24.3	24.8

Units: Wind speed cm/sec, temperature °C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

September 28, 1967

					Wax Blocks (78%)				White Butyl (86%)				Concrete Blks (78%)				Open Tank		
Time	U	T_a	e_a	S	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	Tavg
1	122	21.0	13	0	-.07	19.1	15.6	23.1	-.09	20.1	22.5	23.1	-.06	20.8	19.1	23.1	-.09	21.3	23.9
2	65	20.3	13	0	-.07	19.3	14.8	23.1	-.10	20.3	22.0	22.9	-.06	20.3	18.6	23.1	-.09	21.1	23.7
3	42	19.8	12	0	-.05	19.6	14.3	23.1	-.10	20.3	21.7	22.7	-.06	21.3	18.0	23.0	-.10	20.8	23.3
4	36	19.6	12	0	-.05	19.6	14.2	23.1	-.10	20.3	21.8	22.5	-.06	21.3	18.1	22.9	-.10	20.6	23.0
5	67	20.2	12	0	-.04	19.1	14.5	22.8	-.08	20.1	21.7	22.3	-.05	20.3	18.2	22.6	-.07	18.6	22.6
6	84	20.5	12	0	-.06	18.8	14.9	22.7	-.09	19.8	21.4	22.2	-.05	19.8	17.5	22.4	-.09	19.8	22.4
7	78	19.8	12	.01	-.06	18.8	15.5	22.6	-.10	19.8	21.2	22.1	-.06	20.3	17.1	22.3	-.09	20.3	22.1
8	53	19.8	13	.15	-.01	19.3	17.1	22.6	.02	20.3	22.2	22.0	.01	21.1	18.2	22.3	.05	21.6	22.0
9	126	24.2	13	.47	.14	19.8	25.5	22.5	.19	19.8	25.9	22.0	.15	21.8	22.1	22.3	.33	22.6	22.1
10	166	26.9	13	.68	.25	20.3	30.8	22.5	.25	20.3	29.2	22.1	.33	22.8	25.6	22.4	.54	23.8	22.4
11	143	28.9	13	.90	.37	20.8	35.2	22.6	.39	21.8	28.9	22.2	.44	23.1	28.8	22.5	.80	24.5	22.8
12	267	30.4	12	1.05	.38	20.8	38.3	22.7	.44	23.8	34.5	22.5	.52	24.0	31.5	22.6	.96	25.0	23.4
13	293	31.5	12	1.12	.39	21.1	40.0	22.8	.46	25.3	36.7	22.9	.52	24.5	33.5	22.8	1.03	26.0	24.2
14	207	32.2	12	1.11	.36	21.1	40.8	22.9	.43	26.5	37.9	23.4	.52	25.8	34.8	23.0	.98	26.5	24.8
15	325	32.6	12	1.01	.31	20.8	40.8	23.0	.34	26.2	37.4	23.9	.45	25.8	34.5	23.2	.87	26.7	25.5
16	304	32.8	12	.84	.22	20.8	39.3	23.1	.23	26.2	36.4	24.1	.35	25.8	33.5	23.5	.69	27.0	25.9
17	288	32.5	12	.60	.12	20.3	36.4	23.7	.11	26.0	34.3	24.2	.22	25.0	31.5	23.6	.43	27.2	26.2
18	212	31.7	13	.32	.01	19.3	31.2	23.3	-.02	24.5	31.7	24.1	.07	23.5	28.4	23.7	.17	27.2	25.8
19	110	29.5	13	.03	-.07	19.1	23.0	23.3	-.10	23.1	27.4	24.0	-.06	23.3	23.9	23.7	-.06	24.0	25.2
20	53	26.8	13	0	-.06	18.8	16.7	23.3	-.10	23.1	25.3	23.9	-.06	22.3	21.3	23.6	-.09	23.6	24.8
21	59	24.6	13	0	-.05	18.6	15.4	23.3	-.10	23.1	24.6	23.6	-.06	22.1	19.9	23.4	-.10	23.8	24.5
22	55	23.0	13	0	-.06	18.3	14.9	23.2	-.10	21.8	23.1	23.4	-.06	21.8	19.2	23.2	-.10	23.1	24.3
23	28	21.9	13	0	-.05	19.1	14.5	23.2	-.11	21.3	22.5	23.1	-.06	21.6	18.6	23.1	-.10	22.3	24.0
24	44	21.2	12	0	-.05	19.3	14.3	23.1	-.10	21.1	22.2	23.0	-.06	21.3	18.2	23.0	-.10	22.3	23.9
Avg	134	25.5	13			19.7	24.1	23.0		22.3	27.2	23.0		22.5	23.8	23.0		23.3	23.9

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

September 29, 1967

Time	U	T_a	e_a	S	Wax Blocks (78%) R_n	T_w	T_c	Tavg	White Butyl (86%) R_n	T_w	T_c	Tavg	Concrete Blks (78%) R_n	T_w	T_c	Tavg	Open Tank R_n	T_w	Tavg
1	68	20.5	11	0	-.06	19.1	14.3	22.9	-.10	20.3	21.7	22.7	-.06	21.3	17.9	22.9	-.09	22.3	23.8
2	56	20.0	11	0	-.06	18.6	14.1	22.8	-.10	20.3	21.4	22.6	-.06	21.1	17.6	22.7	-.10	22.1	23.4
3	51	19.6	12	0	-.06	18.6	13.5	22.6	-.10	20.3	21.2	22.4	-.06	21.3	17.4	22.6	-.10	20.8	23.1
4	47	19.2	12	0	-.06	18.6	13.0	22.5	-.10	20.1	21.1	22.3	-.06	21.1	17.2	22.5	-.10	19.6	22.7
5	55	18.8	12	0	-.07	17.8	13.1	22.4	-.10	20.1	21.0	22.1	-.06	20.8	17.0	22.4	-.10	20.3	22.4
6	70	18.5	12	0	-.07	17.6	13.4	22.4	-.10	19.8	21.0	22.0	-.06	19.8	16.8	22.2	-.09	19.8	22.1
7	78	18.3	12	.01	-.07	18.3	13.9	22.3	-.10	19.6	21.1	21.9	-.06	20.3	16.7	22.1	-.10	20.3	21.9
8	80	19.8	13	.13	-.01	18.3	16.4	22.3	.01	19.6	21.9	21.8	-.02	20.1	18.5	22.0	.02	19.8	21.6
9	146	23.6	14	.41	.10	18.3	24.2	22.2	.16	19.6	24.4	21.8	.19	21.3	23.4	22.0	.26	21.6	21.6
10	159	26.7	15	.67	.18	20.3	31.8	22.3	.27	21.3	29.1	21.9	.34	23.1	28.4	22.2	.54	24.0	22.1
11	150	29.1	15	.89	.25	21.3	37.2	22.4	.38	22.6	32.9	22.0	.44	24.8	32.3	22.3	.78	25.0	22.7
12	180	30.8	14	1.05	.32	21.3	40.4	22.5	.42	24.5	35.6	22.3	.52	25.8	35.4	22.6	.93	25.8	23.5
13	205	31.9	13	1.13	.35	21.6	42.6	22.6	.43	25.8	37.5	22.7	.55	28.2	37.9	22.8	1.00	26.5	24.4
14	178	32.8	13	1.10	.30	22.6	43.6	22.8	.41	27.7	37.7	23.3	.49	28.2	39.0	23.0	1.00	27.7	25.3
15	60	33.5	12	1.01	.27	22.3	43.7	23.0	.34	27.7	38.3	23.7	.44	28.2	38.6	23.3	.86	27.7	26.1
16	115	33.9	12	.83	.15	22.3	42.6	23.1	.24	28.7	37.8	24.0	.31	29.4	36.8	23.6	.67	28.4	26.6
17	80	33.9	12	.59	.08	22.3	38.7	23.2	.12	27.5	35.4	24.2	.19	27.7	33.8	23.7	.43	27.7	26.9
18	75	33.3	14	.30	.01	21.3	31.4	23.2	-.01	27.0	31.9	24.2	.05	26.7	29.7	23.7	.16	27.5	26.9
19	30	31.9	14	.03	-.05	20.0	22.7	23.2	-.10	25.8	28.5	24.2	-.06	24.8	23.7	23.7	-.08	24.8	26.6
20	123	29.4	14	0	-.05	19.3	19.0	23.1	-.10	23.5	26.4	24.1	-.07	23.3	22.4	23.6	-.09	24.5	26.3
21	65	26.3	14	0	-.06	19.3	17.4	23.1	-.11	22.6	25.0	23.8	-.07	22.6	21.5	23.5	-.10	23.5	26.0
22	42	24.4	14	0	-.06	19.3	16.7	23.1	-.09	22.1	24.1	23.4	-.05	22.3	20.9	23.3	-.08	23.5	25.7
23	36	23.1	14	0	-.06	19.3	16.5	23.0	-.07	21.8	23.5	23.2	-.04	22.3	20.5	23.2	-.08	23.3	25.3
24	117	22.4	14	0	-.06	18.8	16.6	23.0	-.09	21.3	23.1	23.1	-.06	21.3	20.2	23.1	-.09	23.1	25.0
Avg	94	25.9	13			19.8	24.9	22.8		22.9	27.6	22.9		23.6	25.2	22.9		23.7	24.3

Units: Wind speed cm/sec, temperature $^{\circ}C$, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

September 30, 1967

					Wax Blocks (78%)				White Butyl (86%)				Concrete Blks (78%)				Open Tank		
Time	U	T_a	e_a	S	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	Tavg
1	39	22.1	14	0	-.02	19.3	17.2	22.9	-.06	21.3	23.0	22.8	-.03	21.3	20.0	23.0	-.06	23.3	24.7
2	55	22.0	13	0	-.02	19.1	17.8	22.8	-.04	21.1	22.9	22.6	-.02	21.3	20.2	22.9	-.05	22.3	24.5
3	69	21.7	13	0	-.02	19.3	17.9	22.7	-.05	20.8	22.6	22.5	-.03	21.8	19.9	22.7	-.05	22.1	24.2
4	65	21.1	12	0	-.04	18.8	16.7	22.6	-.08	20.3	22.0	22.4	-.05	19.8	19.1	22.6	-.09	19.8	23.8
5	70	20.4	12	0	-.05	18.8	14.9	22.5	-.08	20.1	21.3	22.3	-.05	19.3	18.3	22.4	-.09	19.6	23.5
6	82	19.9	11	0	-.05	18.8	14.1	22.4	-.10	20.1	21.0	22.1	-.06	20.8	17.6	22.3	-.10	20.3	23.2
7	79	19.5	11	0	-.06	18.1	14.5	22.3	-.10	19.8	21.2	22.0	-.06	20.8	17.0	22.2	-.09	20.8	22.9
8	74	19.7	12	.13	-.01	18.3	17.0	22.2	.01	19.6	21.8	21.9	-.02	21.6	18.0	22.1	.01	21.3	22.7
9	40	25.0	13	.39	.08	20.1	26.0	22.2	.15	20.1	24.8	21.9	.23	24.0	25.0	22.3	.25	25.0	22.9
10	107	28.1	13	.66	.16	21.6	33.1	22.5	.28	22.3	29.1	22.1	.33	25.8	30.4	22.5	.54	25.8	23.2
11	111	30.3	13	.88	.21	22.1	38.4	22.7	.37	23.1	33.0	22.3	.41	26.7	35.3	22.7	.76	25.8	23.8
12	94	32.0	13	1.02	.31	22.3	42.2	22.8	.41	25.8	36.7	22.9	.46	28.2	38.9	23.0	.92	27.2	24.7
13	126	33.3	13	1.10	.33	23.1	45.3	23.0	.41	28.6	40.0	23.6	.44	29.4	41.4	23.3	1.01	29.7	26.0
14	119	34.1	13	1.01	.29	22.6	45.2	23.1	.34	28.7	40.6	23.9	.45	29.7	40.6	23.5	.89	28.9	26.9
15	134	34.6	13	.89	.18	23.1	44.0	23.2	.25	29.4	39.6	24.2	.34	29.9	37.8	23.7	.82	28.7	27.4
16	184	34.8	14	.26	.13	21.3	37.2	23.2	.16	27.2	35.9	24.3	.25	27.0	33.5	23.8	.61	29.4	27.7
17	183	34.4	14	.38	.03	20.8	31.5	23.2	.01	26.2	32.4	24.3	.11	27.0	29.9	23.9	.27	28.9	27.7
18	267	33.1	14	.06	-.03	19.6	27.8	23.1	-.06	24.8	29.9	24.3	-.03	25.0	27.5	23.9	-.01	27.0	27.5
19	70	31.7	15	.01	-.01	19.6	25.5	23.1	-.04	24.3	28.2	24.2	-.02	24.0	26.1	23.9	-.02	26.2	27.1
20	51	30.3	15	0	-.02	20.3	24.0	23.3	-.04	23.8	27.0	24.1	-.03	23.3	25.1	24.0	-.03	25.3	26.8
21	74	29.0	15	0	-.04	20.8	23.0	23.3	-.06	23.3	26.2	23.9	-.04	23.5	24.4	23.8	-.05	24.8	26.5
22	95	27.7	16	0	-.05	21.1	21.9	23.1	-.07	24.5	25.3	23.7	-.06	23.3	23.6	23.6	-.06	24.5	26.1
23	159	26.5	16	0	-.05	21.1	21.0	23.0	-.08	22.3	24.6	23.4	-.05	22.3	22.5	23.3	-.08	22.8	25.7
24	83	25.3	16	0	-.05	20.8	20.5	22.9	-.08	22.3	24.0	23.3	-.05	21.6	21.7	23.2	-.07	22.1	25.2
Avg	101	26.5	14			20.5	26.5	22.8		23.3	28.0	23.1		24.1	26.4	23.1		24.7	25.2

Units: Wind speed cm/sec, temperature ^{o}C. radiation ly/min. vapor pressure mb

Table 14--Continued

Meteorological Data

October 18, 1967

Time	U	T_a	e_a	S	Wax Blocks (78%) R_n	T_w	T_c	Tavg	White Butyl (86%) R_n	T_w	T_c	Tavg	Styrofoam (80%) R_n	T_w	T_c	Tavg	Open Tank R_n	T_w	Tavg
1	61	15.4	6	0	-.07	12.6	7.3	16.6	-.10	13.6	14.8	15.8	-.05	17.3	7.8	18.2	-.11	14.8	18.5
2	60	15.0	6	0	-.06	14.3	7.2	16.5	-.10	13.3	14.6	15.7	-.03	17.3	7.2	18.1	-.11	15.1	18.0
3	45	14.9	6	0	-.06	13.3	7.2	16.4	-.10	13.3	14.4	15.5	-.03	17.1	7.7	18.1	-.11	12.1	17.6
4	74	14.8	6	0	-.08	12.8	7.3	16.3	-.10	13.1	14.3	15.4	-.05	17.1	8.7	18.0	-.11	14.3	17.2
5	43	14.6	6	0	-.06	14.1	6.6	16.2	-.10	12.8	14.2	15.2	-.03	17.1	8.6	17.9	-.11	14.3	16.9
6	71	14.1	6	0	-.07	12.8	6.2	16.1	-.11	12.8	14.3	15.0	-.04	16.8	7.4	17.8	-.12	13.1	16.6
7	76	13.4	6	0	-.08	12.6	6.8	16.0	-.11	12.6	14.1	14.9	-.04	16.8	6.4	17.7	-.11	13.3	16.5
8	121	13.7	6	.08	-.02	13.8	7.9	16.0	-.04	14.1	14.2	14.8	-.02	17.1	10.1	17.7	-.06	14.6	16.5
9	113	20.5	6	.36	.06	14.3	19.1	16.0	.10	13.3	18.0	14.9	.02	17.1	18.4	17.6	.18	19.8	16.8
10	86	24.4	7	.63	.14	17.3	27.5	16.1	.27	14.6	22.1	15.1	.07	17.8	24.8	17.7	.47	20.8	17.1
11	49	27.2	7	.85	.23	19.3	32.8	16.2	.43	16.3	26.4	15.3	.11	18.3	29.1	17.7	.71	21.1	17.6
12	151	29.5	7	.96	.27	20.8	35.9	16.5	.39	18.6	30.4	15.8	.15	19.1	32.2	17.7	.82	23.1	18.2
13	396	31.2	7	1.07	.33	21.8	37.9	16.8	.42	19.3	34.0	16.4	.17	18.6	34.5	17.9	.96	20.8	18.9
14	281	32.5	6	1.04	.31	22.3	39.5	17.1	.36	22.1	36.1	16.9	.15	19.6	35.3	18.0	.91	23.8	19.6
15	246	33.1	6	.95	.26	22.3	38.7	17.2	.30	23.3	36.5	17.2	.12	19.8	34.6	18.1	.81	24.3	20.3
16	194	33.2	6	.76	.18	22.3	36.3	17.3	.20	23.3	34.8	17.3	.06	19.8	32.8	18.3	.61	24.3	20.9
17	155	32.3	6	.50	.07	22.1	32.2	17.3	.04	23.1	30.9	17.4	-.01	19.8	29.2	18.5	.30	23.5	21.1
18	112	30.0	7	.21	-.05	19.6	24.6	17.2	-.10	20.3	24.8	17.3	-.04	19.3	22.1	18.6	.02	21.6	20.9
19	28	25.5	7	0	-.05	13.8	13.1	17.0	-.12	19.3	19.9	17.1	-.03	18.6	11.1	18.7	-.11	17.6	20.6
20	39	21.5	7	0	-.06	14.6	9.8	16.9	-.11	17.1	18.2	16.9	-.03	17.8	8.6	18.7	-.12	16.3	20.3
21	32	18.9	7	0	-.08	12.8	8.2	16.8	-.11	16.6	17.5	16.6	-.04	17.8	7.3	18.5	-.11	18.1	20.0
22	40	17.6	7	0	-.06	13.6	7.1	16.7	-.11	15.8	16.6	16.4	-.03	17.6	6.8	18.4	-.12	16.6	19.6
23	57	16.6	6	0	-.06	13.8	6.2	16.6	-.11	15.1	15.6	16.1	-.04	17.3	6.0	18.3	-.12	17.3	19.3
24	55	15.7	6	0	-.06	13.1	5.5	16.5	-.11	14.3	14.8	15.9	-.03	17.1	4.8	18.2	-.12	14.3	19.0
Avg	108	21.9	6			16.3	18.0	16.6		16.6	21.3	16.0		18.0	16.7	18.1		18.1	18.7

Units: Wind speed cm/sec, temperature °C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

October 19, 1967

Time	U	T_a	e_a	S	Wax Blocks (78%) R_n	T_w	T_c	Tavg	White Butyl (86%) R_n	T_w	T_c	Tavg	Styrofoam (80%) R_n	T_w	T_c	Tavg	Open Tank R_n	T_w	Tavg
1	43	14.7	6	0	-.06	13.6	4.5	16.4	-.11	14.1	14.3	15.7	-.03	17.1	3.5	18.1	-.13	16.1	18.7
2	43	13.6	6	0	-.06	13.6	4.3	16.3	-.11	15.8	13.9	15.5	-.03	17.6	3.0	18.0	-.13	16.6	18.3
3	31	12.4	6	0	-.05	13.8	3.9	16.2	-.11	15.1	13.6	15.3	-.03	17.3	3.0	17.9	-.12	17.3	17.9
4	37	11.6	6	0	-.08	13.1	3.5	16.1	-.11	12.8	13.5	15.1	-.03	16.6	3.5	17.8	-.12	15.8	17.6
5	36	12.3	5	0	-.08	12.8	3.2	15.9	-.11	12.8	13.4	14.9	-.04	16.6	4.2	17.7	-.12	12.8	17.2
6	64	13.0	6	0	-.08	13.8	4.0	15.8	-.11	12.8	13.3	14.7	-.03	16.6	5.1	17.6	-.12	15.1	16.8
7	60	13.3	6	0	-.08	12.6	5.3	15.7	-.11	12.6	13.4	14.6	-.04	16.3	6.7	17.5	-.11	13.8	16.4
8	64	14.1	6	.07	-.03	12.6	7.7	15.7	-.04	12.6	13.9	14.5	-.04	16.6	9.7	17.4	-.11	14.6	16.3
9	89	18.0	6	.35	.07	15.3	17.1	15.7	.10	12.8	16.3	14.6	-.03	16.8	16.0	17.4	-.07	17.8	16.3
10	130	21.9	7	.62	.15	17.3	25.5	15.8	.25	13.8	21.5	15.0	.04	17.3	23.0	17.3	.15	18.3	16.6
11	138	25.0	7	.84	.23	19.6	31.8	16.0	.40	15.8	30.5	15.5	.10	18.1	27.7	17.4	.44	20.1	17.1
12	134	27.4	7	.99	.27	21.3	35.9	16.3	.43	18.3	37.0	15.9	.12	19.1	30.9	17.5	.69	21.6	17.9
13	137	29.1	6	1.06	.34	21.8	38.1	16.6	.42	20.8	39.3	16.2	.14	18.8	33.0	17.6	.84	23.8	18.8
14	136	30.4	6	1.04	.29	22.3	39.3	16.8	.37	22.8	40.5	16.8	.16	19.3	33.9	17.8	.98	23.3	19.7
15	128	31.5	6	.94	.25	23.5	38.9	16.9	.28	23.3	39.9	17.1	.14	20.1	33.6	18.0	.88	24.3	20.5
16	303	31.9	6	.75	.15	22.3	36.4	16.9	.17	23.3	36.4	17.3	.11	20.3	32.3	18.2	.78	23.5	21.0
17	101	31.8	6	.49	.06	21.6	31.9	16.9	.07	22.3	31.2	17.1	-.02	19.8	29.0	18.3	.29	23.1	21.1
18	98	30.6	6	.20	-.05	19.3	24.7	16.8	-.10	20.3	24.4	16.9	-.03	19.1	22.6	18.4	.02	21.3	20.9
19	51	27.0	6	0	-.07	17.3	25.8	16.7	-.11	17.8	18.6	16.7	-.03	18.3	12.6	18.3	-.10	19.3	20.5
20	58	22.0	6	0	-.08	16.3	11.2	16.7	-.11	17.6	15.5	16.4	-.05	17.8	8.6	18.2	-.10	18.3	20.2
21	50	19.4	6	0	-.06	14.8	9.3	16.6	-.11	16.6	13.6	16.2	-.03	17.6	7.2	18.0	-.11	15.8	19.8
22	43	17.3	7	0	-.05	15.3	8.3	16.5	-.11	16.3	12.6	16.0	-.03	17.3	6.4	17.9	-.12	16.8	19.5
23	36	15.9	7	0	-.06	14.3	7.5	16.4	-.11	15.3	11.9	15.8	-.02	17.1	6.0	17.8	-.12	15.8	19.1
24	63	15.0	7	0	-.05	14.6	7.0	16.4	-.10	14.6	11.4	15.6	-.03	17.1	5.9	17.7	-.11	15.8	18.8
Avg	86	20.8	6			16.8	17.3	16.3		16.7	21.2	15.8		17.9	15.3	17.8		18.4	18.6

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

October 20, 1967

Time	U	T_a	e_a	S	Wax Blocks (78%) R_n	T_w	T_c	Tavg	White Butyl (86%) R_n	T_w	T_c	Tavg	Styrofoam (80%) R_n	T_w	T_c	Tavg	Open Tank R_n	T_w	Tavg
1	66	14.5	7	0	-.08	13.3	6.8	16.3	-.10	14.3	11.2	15.3	-.04	16.8	5.8	17.6	-.11	14.8	18.5
2	57	13.8	7	0	-.07	14.3	6.9	16.2	-.10	14.3	10.8	15.1	-.04	16.8	6.3	17.5	-.11	16.3	18.2
3	73	12.9	7	0	-.08	14.3	5.8	16.1	-.11	13.8	10.2	15.0	-.04	16.8	6.6	17.4	-.12	15.1	17.9
4	40	11.6	7	0	-.06	13.8	4.5	16.0	-.11	13.6	9.6	14.8	-.03	16.6	5.8	17.3	-.12	14.8	17.6
5	55	10.6	7	0	-.06	11.8	4.7	15.9	-.11	13.3	9.4	14.7	-.05	16.3	5.3	17.2	-.12	12.8	17.2
6	107	11.1	7	0	-.08	11.8	6.7	15.8	-.11	13.3	9.6	14.6	-.05	16.6	6.0	17.1	-.11	12.6	16.9
7	132	12.2	7	0	-.08	13.8	8.3	15.7	-.11	12.8	9.8	14.5	-.05	16.3	7.5	17.1	-.11	13.3	16.4
8	111	11.4	7	.03	-.06	12.8	7.5	15.5	-.11	13.1	9.6	14.4	-.04	16.3	8.8	17.0	-.10	12.3	16.1
9	50	14.3	7	.29	.05	13.8	15.0	15.5	.05	12.3	14.4	14.6	.03	16.6	12.9	16.9	.14	15.8	16.1
10	154	20.0	7	.57	.14	17.1	23.4	15.6	.23	13.8	21.8	14.9	.08	16.8	21.0	16.9	.39	17.6	16.3
11	171	23.5	7	.81	.22	18.6	29.0	15.7	.41	15.3	29.0	15.2	.10	17.3	26.4	16.9	.66	19.3	16.6
12	234	26.0	7	.98	.29	20.1	32.8	16.0	.41	17.3	34.6	15.6	.14	17.8	29.9	17.0	.82	20.3	17.2
13	182	28.1	7	1.05	.29	21.6	36.3	16.4	.42	20.8	38.6	16.2	.16	18.6	32.1	17.1	.88	22.1	18.1
14	130	29.9	6	1.05	.28	23.3	38.9	16.6	.39	22.6	40.0	16.6	.14	19.1	33.3	17.3	.90	23.5	19.1
15	138	31.3	6	.97	.26	23.1	38.7	16.8	.32	24.5	39.4	16.9	.11	19.3	33.4	17.5	.82	24.5	20.0
16	107	32.1	6	.82	.20	23.1	37.4	16.9	.23	25.0	37.4	17.0	.07	20.1	32.5	17.9	.67	24.0	20.5
17	105	31.9	6	.60	.10	22.6	33.7	16.9	.10	24.5	33.4	17.0	.02	19.8	29.9	18.0	.41	23.5	20.7
18	42	30.8	6	.31	-.03	20.1	27.5	16.7	-.06	22.6	26.4	16.8	-.03	19.3	23.1	18.0	.15	22.1	20.7
19	22	28.0	7	0	-.05	17.6	14.8	16.5	-.11	19.3	17.8	16.7	-.03	18.3	10.9	17.9	-.09	19.3	20.4
20	130	23.6	7	0	-.05	15.6	9.5	16.4	-.11	17.1	15.4	16.5	-.03	17.6	8.4	17.9	-.11	16.3	20.0
21	39	20.6	7	0	-.05	14.6	8.7	16.3	-.11	15.3	13.9	16.3	-.03	17.3	7.0	17.8	-.11	17.6	19.6
22	67	18.1	7	0	-.05	14.8	8.3	16.2	-.11	16.1	12.9	16.1	-.03	17.1	6.4	17.7	-.11	16.6	19.2
23	116	16.2	7	0	-.05	13.3	8.0	16.1	-.10	15.6	12.0	15.9	-.02	17.1	6.1	17.6	-.10	13.8	18.9
24	110	15.9	7	0	-.05	13.0	7.6	16.0	-.10	15.0	11.4	15.7	-.02	17.1	6.0	17.6	-.11	11.1	18.6
Avg	102	20.4	7			16.6	17.5	16.2		16.9	19.5	15.7		17.6	15.5	17.4		17.5	18.4

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

August 1, 1968

Time	U	T_a	e_a	S	R_n	T_w	T_c	Tavg	Rn	T_w	T_c	Tavg	Rn	T_w	Tavg
					White Butyl (86%)				Styrofoam (80%)				Open Tank		
1	36	26.9	26	0	-.05	26.7	26.4	26.7	-.02	27.5	19.8	28.7	-.08	29.0	30.7
2	62	26.3	24	0	-.05	26.4	25.8	26.6	-.02	27.5	19.2	28.6	-.08	28.6	30.4
3	42	25.3	25	0	-.06	26.1	25.5	26.5	-.03	27.2	19.4	28.4	-.09	27.7	30.0
4	66	24.4	26	0	-.05	25.9	25.2	26.4	-.03	27.0	19.0	28.3	-.09	28.2	29.6
5	67	23.9	24	0	-.05	25.7	25.1	26.2	-.03	27.1	17.8	28.2	-.10	28.2	29.3
6	35	24.4	24	.03	-.06	25.5	25.0	26.1	-.02	27.3	17.6	28.2	-.07	27.5	29.2
7	48	26.9	26	.32	0	25.8	25.1	25.9	.02	27.6	21.4	28.1	.12	28.4	29.1
8	117	29.2	24	.59	.08	26.0	27.6	25.9	.14	27.8	29.1	28.1	.37	27.7	29.3
9	85	31.0	23	.82	.15	26.5	30.7	26.1	.19	28.5	36.4	28.2	.66	28.7	29.6
10	104	32.5	22	1.02	.27	28.0	33.9	26.3	.22	29.9	41.5	28.5	.87	30.5	30.2
11	89	33.8	20	1.21	.30	29.5	37.0	26.5	.22	30.9	44.5	28.7	1.10	31.1	30.9
12	114	34.9	22	1.29	.37	30.8	39.4	26.8	.22	31.5	46.6	29.0	1.13	31.1	31.7
13	127	35.5	21	1.28	.37	32.8	41.1	27.4	.19	31.7	47.9	29.2	1.10	32.3	32.7
14	146	36.1	20	1.21	.39	32.8	40.5	27.7	.19	31.7	47.0	29.4	1.10	32.7	33.4
15	157	36.6	21	1.07	.32	32.2	40.6	27.9	.16	31.6	44.4	29.5	.89	33.6	33.8
16	155	36.9	20	.87	.25	32.9	38.7	28.3	.13	31.4	41.5	29.5	.75	33.8	34.2
17	132	36.8	19	.61	.16	32.6	36.4	28.5	.04	31.0	37.3	29.5	.47	33.3	34.1
18	108	36.2	19	.33	.07	31.7	33.5	28.6	.01	30.5	32.3	29.6	.01	32.8	33.7
19	62	34.5	19	.04	-.02	31.1	31.0	28.6	-.03	29.9	26.3	29.6	-.05	32.6	33.2
20	70	32.3	24	0	-.06	30.2	29.6	28.5	-.03	29.1	22.8	29.6	-.09	32.1	32.7
21	264	30.5	22	0	-.06	28.8	28.7	28.3	-.04	28.4	24.0	29.4	-.08	31.0	32.2
22	106	29.1	23	0	-.06	28.2	28.1	27.9	-.01	28.2	24.8	29.3	-.05	31.4	31.7
23	230	27.9	24	0	-.06	27.5	27.4	27.6	-.03	28.0	24.3	29.2	-.06	30.2	31.1
24	170	27.2	24	0	-.06	27.3	26.8	27.3	-.03	28.0	23.5	29.1	-.07	30.2	30.6
Avg	108	30.8	23	-	-	28.8	31.2	27.2	-	29.1	30.4	28.9	-	30.5	31.4

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

August 2, 1968

Time	U	T_a	e_a	S	White Butyl (86%) R_n	T_w	T_c	Tavg	Styrofoam (80%) R_n	T_w	T_c	Tavg	Open Tank R_n	T_w	Tavg
1	97	26.7	24	0	-.01	27.1	26.4	27.2	-.02	28.0	23.1	29.0	-.06	29.9	30.2
2	124	26.5	24	0	-.01	26.7	26.2	27.0	-.02	27.8	23.1	28.9	-.05	29.4	29.8
3	187	26.2	24	0	-.06	26.3	26.2	26.9	-.02	27.6	24.1	28.7	-.04	29.2	29.4
4	352	24.7	24	0	-.07	25.9	25.7	26.8	-.01	27.4	23.1	28.6	-.04	28.7	29.0
5	117	23.6	23	0	-.06	25.7	25.1	26.7	-.01	27.4	21.0	28.5	-.05	28.2	28.5
6	107	23.6	24	.04	-.06	25.8	24.8	26.6	-.02	27.7	19.6	28.4	-.05	27.7	28.0
7	88	24.8	25	.32	.02	26.2	26.0	26.5	.00	28.1	24.5	28.3	.13	28.2	28.1
8	108	27.1	25	.60	.16	26.7	28.3	26.4	.16	28.7	30.8	28.3	.51	28.4	28.4
9	156	28.9	24	.83	.25	27.5	30.8	26.3	.19	29.3	36.5	28.5	.66	28.9	28.9
10	129	30.4	24	1.03	.29	28.7	33.8	26.4	.18	30.0	40.1	28.8	.75	29.5	29.5
11	150	31.9	23	1.19	.34	30.2	38.5	26.7	.22	30.2	45.0	29.0	1.02	30.0	30.3
12	163	33.3	23	1.29	.41	31.7	40.0	27.0	.18	30.6	47.1	29.2	1.16	30.7	31.2
13	149	34.4	22	1.29	.41	32.9	40.4	27.4	.17	31.1	47.2	29.3	1.19	31.6	32.0
14	156	35.3	22	1.22	.32	33.8	40.2	27.8	.12	31.4	45.8	29.5	1.09	32.3	32.8
15	137	35.8	22	1.07	.29	34.2	39.6	28.1	.09	31.5	43.7	29.6	.92	33.1	33.5
16	118	36.1	23	.86	.20	33.7	38.5	28.4	.11	31.3	41.1	30.0	.73	33.5	33.9
17	123	36.1	21	.60	.12	40.0	36.6	28.7	.07	30.8	37.8	30.0	.47	33.5	34.0
18	100	35.8	21	.33	.04	33.1	34.0	28.9	.01	30.8	33.0	29.7	.10	33.5	33.7
19	73	34.7	22	.07	-.02	31.7	31.1	29.0	-.03	30.0	27.0	29.6	.03	33.3	33.3
20	55	31.5	26	0	-.05	30.8	29.5	29.0	-.02	29.6	21.6	29.7	-.09	33.1	33.0
21	37	29.6	26	0	-.06	29.9	28.8	29.0	-.02	29.3	20.3	29.7	-.09	32.6	32.7
22	51	28.6	25	0	-.05	29.1	28.2	28.8	-.01	29.1	21.7	29.6	-.07	32.1	32.3
23	118	27.9	24	0	-.05	28.3	27.6	28.6	-.03	28.8	22.3	29.4	-.07	31.4	31.8
24	78	27.3	25	0	-.06	27.7	27.1	28.2	-.02	28.6	22.5	29.2	-.08	31.1	31.3
Avg	124	30.3	24	-	-	29.7	31.4	27.6	-	29.4	30.9	29.1	-	30.8	31.1

Units: Wind speed cm/sec, temperature °C. radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

August 14, 1968

Time	U	T_a	e_a	S	Styrofoam (87%) R_n	T_w	T_c	Tavg	Styrofoam (51%) R_n	T_w	T_c	Tavg	Styrofoam (26%) R_n	T_w	T_c	Tavg	Open Tank R_n	T_w	Tavg
1	53	23.0	10	0	-.03	26.5	11.0	27.6	-.08	27.0	8.5	28.1	-.10	25.9	6.0	27.6	-.13	25.5	27.3
2	106	22.0	11	0	-.03	26.3	11.0	27.4	-.07	26.7	9.0	27.8	-.09	25.7	7.0	27.4	-.12	25.0	26.8
3	45	20.6	13	0	-.03	26.3	10.2	27.3	-.08	26.4	8.1	27.7	-.10	25.5	6.0	27.2	-.13	24.5	26.7
4	87	19.3	14	0	-.03	26.3	9.5	27.2	-.08	26.1	7.3	27.4	-.10	25.0	5.1	26.8	-.13	24.0	26.1
5	75	18.0	14	0	-.03	26.2	9.5	27.3	-.08	25.9	7.2	27.2	-.10	24.8	4.8	26.6	-.13	23.8	25.8
6	47	17.5	14	.03	-.04	26.1	10.0	27.1	-.08	25.6	7.6	27.0	-.09	24.5	5.2	26.4	-.11	23.6	25.3
7	108	20.6	14	.29	-.03	26.2	14.5	26.9	.01	25.7	11.3	26.7	.05	24.4	8.0	26.0	.08	23.7	25.1
8	97	23.3	13	.58	-.01	26.8	23.1	26.9	.17	26.3	18.7	26.6	.24	24.4	14.3	26.2	.34	24.2	25.0
9	93	25.6	12	.86	.03	27.8	30.5	26.9	.27	26.9	25.1	26.9	.44	24.9	19.7	26.4	.61	24.7	25.9
10	85	28.3	11	1.09	.11	28.6	36.1	27.1	.42	27.3	29.9	27.1	.65	25.3	23.6	26.7	.87	25.2	26.3
11	194	31.0	10	1.25	.16	29.1	40.5	27.1	.52	27.5	33.6	27.4	.78	25.7	26.6	27.2	1.04	25.7	26.9
12	217	32.0	10	1.33	.18	29.3	43.2	27.2	.56	27.8	36.0	27.7	.84	26.1	28.8	27.5	1.12	26.1	27.5
13	149	32.9	9	1.33	.19	29.3	44.1	27.7	.58	28.0	36.9	28.2	.86	26.7	29.7	28.1	1.14	26.9	28.4
14	162	33.6	9	1.27	.17	28.3	43.1	27.6	.54	28.1	36.3	28.4	.81	27.0	29.5	28.6	1.07	27.5	29.1
15	199	33.5	9	1.12	.13	28.2	40.0	27.6	.46	28.1	34.0	28.6	.69	26.9	28.0	28.9	.92	27.7	29.5
16	196	33.3	8	.90	.07	27.5	36.5	27.6	.33	27.8	30.9	28.7	.51	26.7	25.3	28.9	.69	27.7	29.7
17	186	32.8	7	.61	-0	27.0	31.5	27.4	.17	27.4	26.8	28.4	.29	26.4	22.0	28.6	.41	27.5	29.4
18	163	31.6	8	.30	-.06	26.5	25.0	27.3	.01	27.0	21.1	28.4	.06	26.3	17.2	28.3	.10	26.9	28.9
19	118	29.8	8	.02	-.05	26.5	17.5	27.3	-.08	26.7	13.6	28.1	-.09	26.1	9.7	28.1	-.10	26.1	28.3
20	54	27.0	9	0	-.05	26.6	11.5	27.2	-.09	26.4	9.4	27.9	-.11	25.8	7.2	27.8	-.14	25.2	27.7
21	84	26.1	10	0	-.03	26.3	9.5	27.0	-.08	26.2	7.3	27.6	-.10	25.6	5.0	27.3	-.13	24.5	27.1
22	63	26.1	10	0	-.02	26.3	8.0	27.0	-.07	26.1	6.1	27.4	-.10	25.3	4.2	27.1	-.13	24.2	26.6
23	36	20.8	11	0	-.04	26.3	7.5	26.9	-.09	25.9	5.4	27.2	-.11	25.0	3.2	26.8	-.14	23.9	26.3
24	46	18.5	11	0	-.04	26.1	7.0	27.1	-.09	25.7	4.6	27.0	-.12	24.6	2.2	26.6	-.15	23.7	25.9
Avg	111	26.1	11	-	-	27.1	22.1	27.2	-	27.9	18.1	27.6	-	25.6	14.1	26.2	-	25.3	25.9

Units: Wind speed cm/sec, temperature °C, radiation ly/min. vapor pressure mb

Table 14--Continued

Meteorological Data

August 15, 1968

					Styrofoam (87%)				Styrofoam (51%)				Styrofoam (26%)				Open Tank		
Time	U	T_a	e_a	S	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	Tavg
1	33	17.7	12	0	-.04	25.9	6.5	26.7	-.09	25.4	4.0	26.7	-.11	24.3	1.4	26.2	-.15	23.4	25.3
2	39	16.9	12	0	-.04	25.7	5.5	26.8	-.09	25.2	3.7	26.5	-.11	24.0	1.8	25.9	-.14	23.0	25.0
3	102	16.2	12	0	-.05	25.4	7.5	26.6	-.09	24.8	5.3	26.1	-.11	23.5	3.0	25.4	-.14	22.2	24.5
4	107	15.5	12	0	-.05	25.1	8.0	26.5	-.10	24.4	5.5	25.9	-.12	23.0	3.0	24.9	-.14	21.5	23.9
5	153	15.7	12	0	-.05	25.0	8.0	26.2	-.09	24.0	5.2	25.5	-.11	22.3	2.4	24.6	-.13	21.1	23.3
6	86	15.2	13	.03	-.05	25.0	7.0	26.1	-.09	23.7	4.4	25.2	-.11	21.9	1.8	24.3	-.12	21.0	22.9
7	91	17.1	13	.30	-.03	25.4	11.5	26.1	.01	23.9	7.9	24.9	.05	22.1	4.3	24.1	.09	21.3	22.8
8	99	22.3	13	.60	-.02	26.3	22.0	26.0	.13	24.3	15.6	24.9	.24	22.6	9.2	24.0	.36	22.2	22.6
9	120	26.2	13	.87	.04	26.7	30.0	25.9	.28	24.7	23.2	24.9	.46	23.1	16.5	24.2	.64	23.0	23.2
10	147	28.2	13	1.10	.10	27.0	36.0	26.1	.41	25.1	29.1	25.2	.64	23.7	22.2	24.7	.87	23.7	24.0
11	133	29.9	13	1.26	.13	28.0	41.0	26.4	.50	25.6	33.5	25.9	.76	24.3	25.9	25.3	1.03	24.2	24.9
12	131	31.6	12	1.34	.12	28.9	45.0	26.5	.52	26.1	36.8	26.4	.81	24.8	28.5	26.2	1.10	24.5	25.9
13	117	32.6	12	1.34	.14	29.2	45.5	26.8	.54	26.5	37.9	26.8	.82	25.3	30.4	26.6	1.11	25.5	26.9
14	129	33.4	11	1.26	.14	29.1	43.1	27.0	.51	26.8	36.8	27.1	.77	25.7	30.4	27.3	1.04	26.6	27.7
15	121	33.6	11	1.09	.10	28.8	41.0	26.8	.42	27.0	34.8	27.0	.65	25.9	28.5	27.7	.88	27.1	28.5
16	137	33.5	10	.84	.05	28.4	37.5	26.8	.30	26.9	31.5	27.2	.48	26.1	25.5	27.9	.65	27.4	28.7
17	164	33.4	10	.56	0	27.7	32.0	26.8	.16	26.7	26.9	27.2	.28	26.0	21.8	27.9	.38	27.4	28.7
18	143	32.4	10	.28	0	27.1	20.5	26.8	.04	26.4	18.5	27.3	.08	25.7	16.4	27.7	.11	27.0	28.5
19	95	29.9	10	.03	-.03	26.6	16.5	26.7	-.05	26.3	13.4	27.2	-.07	25.8	10.2	27.5	-.09	26.5	27.9
20	36	27.2	11	0	-.04	26.2	14.0	26.5	-.07	26.1	9.8	27.1	-.10	26.0	5.6	27.4	-.12	26.0	27.5
21	36	24.4	11	0	-.02	25.8	10.0	26.4	-.07	26.0	7.3	26.9	-.09	25.5	4.6	27.0	-.13	25.5	27.1
22	33	22.0	12	0	-.03	25.7	9.5	26.3	-.07	25.8	6.7	26.6	-.10	25.3	3.9	26.7	-.13	25.2	26.7
23	38	20.0	13	0	-.02	25.4	9.0	26.1	-.07	25.6	6.1	26.6	-.09	25.1	3.2	26.4	-.13	25.2	26.4
24	32	18.8	14	0	-.02	25.2	8.0	26.1	-.07	25.3	5.5	26.4	-.09	24.5	2.9	26.1	-.13	24.8	26.0
Avg	97	24.7	12	-	-	26.7	21.4	26.5	-	25.5	17.0	26.3	-	24.4	12.6	26.1	-	24.4	25.8

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

August 16, 1968

					Styrofoam (87%)				Styrofoam (51%)				Styrofoam (26%)				Open Tank		
Time	U	T_a	e_a	S	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	Tavg
1	52	18.5	14	0	-.02	25.2	7.5	26.1	-.07	24.9	5.1	26.1	-.09	24.1	2.6	25.9	-.13	24.2	25.5
2	54	18.2	13	0	-.04	25.2	9.0	26.1	-.08	24.7	5.7	25.9	-.10	23.7	2.4	25.5	-.13	23.6	25.1
3	98	17.8	12	0	-.04	25.2	9.5	26.1	-.08	24.4	5.8	25.5	-.10	23.4	2.0	25.1	-.12	23.1	24.6
4	40	16.4	12	0	-.03	25.0	7.0	26.1	-.08	24.0	4.4	25.4	-.10	23.1	1.7	24.9	-.13	22.6	24.3
5	70	15.5	12	0	-.03	24.8	6.0	26.0	-.08	23.8	3.7	25.2	-.10	22.8	1.4	24.7	-.13	22.1	23.9
6	71	15.3	13	.02	-.04	24.8	7.0	25.7	-.08	23.6	5.2	25.0	-.10	22.5	3.3	24.3	-.12	21.7	23.4
7	91	17.8	13	.28	-.03	24.8	10.5	25.4	0	23.7	8.7	24.7	.03	22.4	6.8	24.1	.07	21.4	23.1
8	142	22.0	14	.57	-.01	25.2	21.5	25.4	.13	24.0	16.3	24.6	.24	22.5	11.0	24.0	.35	21.6	23.2
9	146	25.7	15	.86	.04	26.3	31.0	25.4	.28	24.4	23.2	24.8	.46	23.4	15.3	24.3	.63	23.0	23.7
10	174	28.9	15	1.09	.10	27.1	37.5	25.6	.42	24.9	28.8	25.0	.65	24.0	20.0	24.8	.87	23.9	24.4
11	187	31.6	15	1.24	.15	27.5	42.0	25.6	.52	25.5	33.7	25.3	.78	24.4	25.4	25.4	1.05	24.4	25.0
12	210	34.1	14	1.33	.18	27.8	44.5	26.0	.53	26.0	37.7	25.9	.86	24.6	30.8	25.9	1.14	25.0	26.0
13	179	35.6	14	1.33	.18	27.8	46.0	25.9	.58	26.4	39.4	26.1	.87	24.7	32.8	26.4	1.16	25.4	26.9
14	253	36.0	13	1.26	.17	27.8	45.5	26.1	.55	26.6	39.3	26.5	.82	25.0	33.0	26.8	1.08	26.3	27.8
15	271	36.0	13	1.10	.11	27.7	43.5	26.1	.45	26.7	37.6	26.8	.70	25.3	31.7	27.3	.93	26.8	28.2
16	313	36.2	12	.88	.08	27.2	39.0	25.9	.34	26.5	33.7	26.8	.54	25.3	28.4	27.3	.71	27.0	28.4
17	290	35.9	11	.60	.02	26.5	34.0	25.9	.20	26.3	29.8	26.9	.34	25.1	25.5	27.1	.45	27.0	28.3
18	255	35.0	11	.30	-.02	26.6	28.5	25.9	.07	26.0	25.2	26.8	.13	24.9	21.8	26.9	.17	26.8	27.8
19	150	31.8	11	.02	-.06	25.3	22.5	26.1	-.07	25.9	20.2	26.6	-.06	24.7	17.8	26.7	-.08	26.3	26.8
20	126	29.2	11	0	-.05	24.9	19.5	25.9	-.07	25.7	17.1	26.5	-.07	24.4	14.6	26.4	-.10	25.8	26.8
21	93	29.7	11	0	-.02	24.9	15.5	25.6	-.06	25.5	13.8	26.3	-.06	24.2	12.1	26.1	-.10	25.4	26.4
22	70	26.8	11	0	-.02	24.9	13.5	25.7	-.05	25.3	11.9	26.0	-.07	24.0	10.2	25.9	-.10	25.0	26.1
23	51	22.1	12	0	-.03	25.0	13.5	25.7	-.06	25.0	11.2	25.9	-.08	23.7	8.8	25.6	-.10	24.4	25.6
24	155	21.0	14	0	-.04	25.0	14.5	25.6	-.07	24.8	11.4	25.6	-.07	23.4	8.2	25.4	-.10	23.9	25.3
Avg	148	26.5	13	-	-	25.9	23.7	25.8	-	25.2	19.5	25.8	-	24.0	15.3	25.7	-	24.4	25.7

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

August 22, 1968

					Styrofoam (87%)				Styrofoam-1 (76%)				Styrofoam-12 (76%)				Open Tank		
Time	U	T_a	e_a	S	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	T_c	Tavg	R_n	T_w	Tavg
1	49	18.0	16	0	-.05	24.3	9.6	24.9	-.08	24.8	11.7	25.8	-.08	22.1	13.0	25.0	-.15	24.2	26.5
2	69	17.4	16	0	-.05	24.5	8.8	25.0	-.07	24.5	10.6	25.8	-.07	21.7	12.6	25.2	-.15	23.4	26.2
3	74	17.0	15	0	-.04	24.5	8.0	24.7	-.06	24.1	9.7	25.7	-.06	21.6	12.3	24.8	-.14	22.8	25.7
4	80	16.9	16	0	-.03	24.3	7.7	24.5	-.06	24.3	9.0	25.5	-.06	21.4	11.8	24.8	-.13	22.6	25.2
5	74	17.1	16	0	-.04	24.3	8.3	24.5	-.06	24.1	9.6	25.2	-.06	22.2	11.3	24.7	-.13	22.3	24.8
6	58	17.9	16	.01	-.05	23.8	10.9	24.4	-.07	23.8	12.4	25.0	-.07	21.3	12.4	24.5	-.11	21.3	24.4
7	116	19.6	16	.27	-.04	24.3	14.3	24.2	-.03	24.0	15.2	24.7	-.03	21.4	16.2	24.5	.07	21.6	24.0
8	137	22.8	18	.57	0	25.0	18.4	24.4	.03	24.0	20.0	24.9	.03	22.2	20.6	24.4	.33	22.3	24.1
9	106	26.2	17	.86	.08	25.8	23.8	24.5	.14	24.4	25.5	24.9	.14	23.5	25.4	24.5	.62	23.0	24.5
10	65	28.9	16	1.08	.10	26.5	36.3	24.9	.23	25.3	32.5	25.4	.23	24.2	28.7	24.8	.86	24.8	25.5
11	85	31.4	14	1.24	.16	27.0	40.3	24.9	.29	25.5	37.4	25.6	.29	24.2	32.3	24.9	1.04	24.6	26.3
12	109	32.4	13	1.32	.20	27.5	42.0	25.0	.33	26.1	40.2	25.8	.33	23.8	33.7	25.1	1.13	25.5	27.3
13	164	33.3	14	1.33	.22	27.2	42.8	25.3	.36	25.8	40.8	25.8	.36	24.0	34.6	25.4	1.16	25.6	27.9
14	165	33.6	14	1.25	.18	27.2	43.2	25.2	.31	25.6	40.6	26.1	.31	23.7	34.7	25.6	1.07	26.9	28.8
15	233	33.5	13	1.10	.13	26.0	41.0	25.3	.25	25.6	38.7	26.2	.25	23.3	34.0	25.7	.93	25.6	29.0
16	283	33.3	11	.87	.10	25.5	35.5	25.2	.18	25.3	35.0	26.3	.18	22.4	32.1	25.6	.70	26.7	29.2
17	263	32.5	10	.59	.01	25.0	31.3	25.4	.07	25.0	30.8	26.4	.07	23.0	28.8	25.6	.41	26.5	29.0
18	152	31.3	10	.27	-.01	25.0	26.0	25.3	-.01	24.5	26.3	26.3	-.01	22.8	24.3	25.5	.11	26.4	28.4
19	108	29.6	10	.02	-.07	24.8	20.0	25.1	-.08	24.8	20.8	26.3	-.08	22.6	20.6	25.5	-.10	24.9	27.7
20	68	27.3	9	0	-.06	24.3	16.3	24.9	-.08	24.9	17.3	26.0	-.08	22.6	18.3	25.1	-.12	24.7	27.1
21	71	25.1	7	0	-.05	24.0	13.3	24.9	-.06	24.2	14.5	25.9	-.06	22.4	16.3	25.1	-.12	24.0	26.6
22	70	23.2	8	0	-.04	24.3	11.0	24.9	-.06	24.6	12.0	25.9	-.06	23.2	15.0	25.1	-.13	24.0	26.2
23	60	21.4	8	0	-.04	23.3	9.0	25.0	-.07	24.3	10.2	25.8	-.07	22.9	13.9	24.8	-.14	22.9	25.8
24	108	19.5	6	0	-.02	23.8	7.1	24.6	-.04	23.9	8.4	25.5	-.04	22.1	12.7	24.7	-.12	22.7	25.1
Avg	115	25.4	13			25.1	21.9	24.9		24.7	22.1	25.7		22.7	21.5	25.0		24.1	26.5

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

August 23, 1968

Time	U	T_a	e_a	S	Styrofoam (87%) R_n	T_w	T_c	Tavg	Styrofoam-1 (76%) R_n	T_w	T_c	Tavg	Styrofoam-12 (76%) R_n	T_w	T_c	Tavg	Open Tank R_n	T_w	Tavg
1	43	17.7	7	0	-.04	23.8	5.3	24.8	-.06	24.3	6.8	25.4	-.06	22.6	11.4	24.7	-.15	21.9	24.6
2	43	16.0	11	0	-.05	24.0	3.7	24.7	-.07	23.9	5.8	25.5	-.07	22.7	10.6	24.6	-.16	21.4	24.3
3	41	14.4	9	0	-.04	23.5	2.9	24.7	-.07	23.7	4.5	25.1	-.07	22.6	10.0	24.5	-.15	20.9	23.9
4	56	13.1	6	0	-.04	23.8	2.4	24.3	-.06	23.4	3.7	24.9	-.06	21.7	9.6	24.2	-.15	20.1	23.3
5	37	12.0	10	0	-.04	23.5	2.5	24.4	-.06	23.2	3.3	24.8	-.06	22.1	9.4	24.1	-.15	20.2	23.0
6	30	11.8	10	.02	-.05	23.3	3.2	24.3	-.06	23.2	3.9	24.5	-.06	21.3	9.6	23.9	-.14	19.6	22.4
7	39	13.0	12	.27	-.04	24.0	7.0	24.2	-.03	23.7	7.3	24.3	-.03	21.3	10.7	23.8	.05	19.8	22.2
8	60	21.5	10	.56	-.01	24.3	16.0	23.9	.02	23.3	17.2	24.1	.02	21.2	17.1	23.6	.32	19.8	22.0
9	63	25.3	8	.85	.05	25.3	27.8	24.2	.12	24.4	26.6	24.2	.12	23.4	22.0	23.9	.66	21.8	22.7
10	91	28.5	9	1.09	.08	26.2	35.5	24.3	.19	24.3	33.5	24.5	.19	23.7	26.0	24.1	.85	22.9	23.5
11	96	30.6	9	1.25	.12	26.7	40.3	24.5	.26	24.3	37.9	24.9	.26	23.8	28.8	24.1	1.02	23.5	24.5
12	107	32.7	10	1.34	.17	27.5	43.1	24.4	.31	24.8	40.1	25.1	.31	24.0	30.8	24.2	1.13	23.8	25.3
13	136	34.0	11	1.35	.21	27.5	44.3	24.5	.36	25.1	41.2	25.1	.36	24.3	31.5	24.5	1.18	24.8	26.2
14	133	34.2	10	1.26	.19	27.2	43.5	24.7	.33	25.0	41.0	25.3	.33	24.5	32.3	25.0	1.10	25.4	27.0
15	116	34.1	10	1.10	.14	28.2	41.4	24.9	.26	25.4	38.8	25.7	.26	24.5	31.3	25.1	.90	26.3	27.8
16	88	33.7	10	.86	.07	27.7	38.0	24.9	.17	25.1	35.1	25.8	.17	25.0	29.4	25.1	.69	26.7	28.0
17	108	33.2	11	.57	.0	27.7	32.5	25.0	.07	24.6	30.9	26.0	.07	24.6	26.2	25.5	.36	26.9	28.4
18	150	32.2	11	.39	-.02	27.2	25.0	25.1	.01	24.3	25.2	25.8	.01	23.9	22.6	25.2	.19	26.6	28.3
19	132	30.1	11	.02	-.04	25.3	16.5	24.8	-.06	24.8	19.0	25.8	-.06	23.1	19.0	25.1	-.10	24.9	27.5
20	79	29.0	10	0	-.03	25.0	12.6	25.0	-.05	24.8	14.3	25.9	-.05	24.2	16.5	25.2	-.10	24.5	27.3
21	56	26.7	12	0	-.03	24.3	11.1	24.7	-.05	24.6	12.3	25.8	-.05	23.8	16.0	24.9	-.11	23.8	26.9
22	28	24.0	14	0	-.04	24.3	10.3	24.6	-.06	24.5	11.2	25.6	-.06	23.5	15.3	24.8	-.11	23.3	26.4
23	20	21.5	14	0	-.04	24.3	9.5	24.6	-.05	24.4	10.5	25.4	-.05	23.4	14.8	24.8	-.12	22.6	26.1
24	35	19.4	15	0	-.03	24.0	9.0	24.4	-.05	23.9	10.0	25.2	-.05	23.1	14.4	24.6	-.12	22.7	25.7
Avg	75	24.5	10			25.4	20.1	24.6		24.3	20.0	25.2		23.3	19.4	24.6		23.1	25.3

Units: Wind speed cm/sec, temperature ^{o}C, radiation ly/min, vapor pressure mb

Table 14--Continued

Meteorological Data

August 24, 1968

Time	U	T_a	e_a	S	Styrofoam (87%) R_n	T_w	T_c	Tavg	Styrofoam-1 (76%) R_n	T_w	T_c	Tavg	Styrofoam-12 (76%) R_n	T_w	T_c	Tavg	Open Tank R_n	T_w	Tavg
1	40	18.0	14	0	-.03	23.8	8.4	24.4	-.05	23.7	9.4	25.1	-.05	22.8	13.8	24.5	-.12	22.6	25.3
2	48	17.2	13	0	-.03	23.8	7.7	24.5	-.05	23.4	8.8	25.1	-.05	22.7	13.2	24.5	-.13	22.0	25.0
3	34	16.9	12	0	-.04	23.8	7.2	24.4	-.05	23.5	8.1	25.0	-.05	22.6	12.8	24.3	-.12	21.1	24.6
4	35	16.4	11	0	-.03	23.8	6.6	24.2	-.05	23.4	7.6	24.7	-.05	22.1	12.2	24.2	-.12	21.1	24.2
5	24	15.7	12	0	-.04	23.3	6.2	24.2	-.06	23.2	7.1	24.7	-.06	21.9	11.7	24.1	-.13	20.2	23.8
6	21	15.7	11	.01	-.04	23.3	5.9	24.2	-.06	23.0	7.0	24.7	-.06	21.7	11.8	23.9	-.12	20.2	23.5
7	49	18.2	13	.25	-.03	23.8	11.1	24.0	-.03	23.7	12.0	24.1	-.03	21.8	14.7	23.8	.06	21.0	23.1
8	148	22.3	14	.55	0	24.8	18.0	24.0	.02	23.2	21.0	24.3	.02	21.3	19.7	23.8	.32	21.1	23.2
9	164	24.8	12	.85	.03	24.5	30.5	23.9	.13	23.3	28.7	24.3	.13	21.9	24.1	23.9	.64	21.7	23.4
10	155	28.6	13	1.08	.10	25.3	37.1	23.9	.21	23.5	35.2	24.5	.21	23.3	28.3	24.0	.88	21.9	24.0
11	150	32.0	14	1.23	.15	26.7	42.4	24.1	.28	24.6	39.4	24.7	.28	24.3	31.0	24.4	1.04	23.9	25.1
12	121	34.4	12	1.32	.16	27.5	45.7	24.2	.31	25.0	42.3	25.2	.31	25.6	32.7	24.4	1.12	24.8	26.2
13	83	35.7	12	1.33	.14	28.4	46.8	24.6	.30	25.9	44.2	25.4	.30	25.5	33.4	24.6	1.10	26.1	27.2
14	127	36.4	11	1.25	.16	29.2	45.7	24.7	.30	26.0	43.7	25.6	.30	25.1	33.8	25.1	1.08	26.5	28.0
15	160	36.7	12	1.09	.14	27.5	42.9	24.7	.26	25.5	40.8	25.5	.26	24.3	33.5	25.2	.94	26.9	28.6
16	138	36.6	11	.86	.07	26.7	39.3	24.7	.16	25.1	38.0	25.8	.16	24.5	32.0	25.1	.69	27.2	28.8
17	134	36.1	12	.57	.01	26.7	34.5	24.9	.07	24.6	34.0	25.8	.07	23.5	29.5	25.1	.42	27.1	29.0
18	98	34.7	12	.27	-.02	26.5	28.8	24.6	0	24.4	29.4	25.7	0	23.3	26.5	25.2	.15	26.6	28.6
19	97	32.0	13	.02	-.05	25.3	20.3	24.5	-.06	24.6	20.6	25.8	-.06	23.4	20.3	25.0	-.09	26.6	28.1
20	131	28.0	16	0	-.04	25.0	13.1	24.9	-.05	24.9	14.1	26.1	-.05	24.0	16.4	25.2	-.12	25.1	28.0
21	32	25.5	14	0	-.03	24.8	11.8	24.7	-.05	24.6	13.4	25.9	-.05	23.9	16.2	25.2	-.12	24.8	27.5
22	49	24.0	12	0	-.02	24.3	11.2	24.5	-.04	24.3	12.8	25.6	-.04	23.3	15.7	24.8	-.11	24.3	27.1
23	31	22.8	15	0	-.03	24.0	10.8	24.4	-.05	24.0	12.1	25.6	-.05	23.3	15.5	24.7	-.12	24.0	26.7
24	35	21.7	14	0	-.03	23.8	10.4	24.6	-.05	23.9	11.5	25.4	-.05	23.1	15.2	24.7	-.11	23.4	26.4
Avg	88	26.3	13			25.3	22.6	24.4		24.2	22.6	25.2		23.3	21.4	24.6		23.8	26.1

Units: Wind speed cm/sec, temperature °C, radiation ly/min, vapor pressure mb

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