COLORADO AGRICULTURAL EXPERIMENT STATION

Progress Report No. 5

Study of Evaporation from Soil Surfaces in Terms of Soil and Micrometeorological Factors of the Western Regional Research Project W-32 Basic Hydrological Factors Relating to Water Conservation

November, 1959

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Colorado Contributing Project

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in Terms of Soil and Micrometeorological Factors
of the
Western Regional Research Project W-32
Basic Hydrological Factors Relating to
Water Conservation

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COLORADO CONTRIBUTING PROJECT W-32

Progress Report No. 5.

Project Leader: Arthur T. Corey, at the present time on a temporary assignment as Associate Professor of Civil Engineering, SEATO Graduate School of Engineering, Bangkok, Thailand.
Richard A. Schleusener, Assistant Research Engineer is Acting Project Leader in A. T. Corey's absence.

Other Personnel: Larry G. King, Graduate Assistant.

Cooperating Agencies: Colorado Agricultural Experiment Station, Agricultural Research Service, U.S.D.A.

Objectives:

The project is a comprehensive study of evaporation from soil surfaces. The objectives are to evaluate the variables known to affect evaporation from soil and to search for relationships among the pertinent variables which will permit quantitative estimates of evaporation from a given soil under prevailing ambient conditions.

Completed Work:

The first phase of the study dealt with steady-state evaporation from a soil in contact with a water table. The results of this phase have been reported previously (2, 4, 6, 8)*. The ambient conditions of temperature, relative humidity, and incident radiation were maintained at a constant level for any particular run. It was found that under severe evaporating conditions an inverse relationship could exist between the rate of evaporation from a soil in contact with a water table and the

* Numbers refer to appended references.

rate of evaporation from a free-water surface. This phenomenon has been explained in a qualitative manner through a hysteresis hypothesis (6).

The next phase of the study dealt with the effect of surface treatments on evaporation from a soil. The results of most of this work were reported last year (3). Since then a limited study was conducted of the effects of surfactants on evaporation from a bare soil under periodic application of water. The experimental procedures were the same as described previously ~~(13)~~ (3).

Figures 1 and 2 show that with light application of the surfactants, periodic application of water to the surface does not reduce significantly the effectiveness of the surfactant. However, the light application is relatively ineffective in reducing evaporation. With the heavier application of the surfactant, the effectiveness of the surfactant begins to be significantly reduced after the second application of water. The application rates of surfactants for these experiments for light and heavy treatments were 138 and 1383 pounds per acre respectively. At the quoted price of about 30 cents per pound it is believed that unless some significant reduction in price or increased effectiveness of the surfactant can be accomplished, costs for treatment are in excess of benefits gained from the moisture conserved.

<u>New Experiments:</u>

Experiments are being conducted to determine whether or not the inverse relationship mentioned earlier exists under conditions simulating those found in the field. In the field the severe evaporating conditions exist for only a short portion of the diurnal cycle. The control equipment has been modified during the past year so that the temperature, relative humidity, and incident radiation in the environmental control chamber will automatically undergo a diurnal cyclic variation

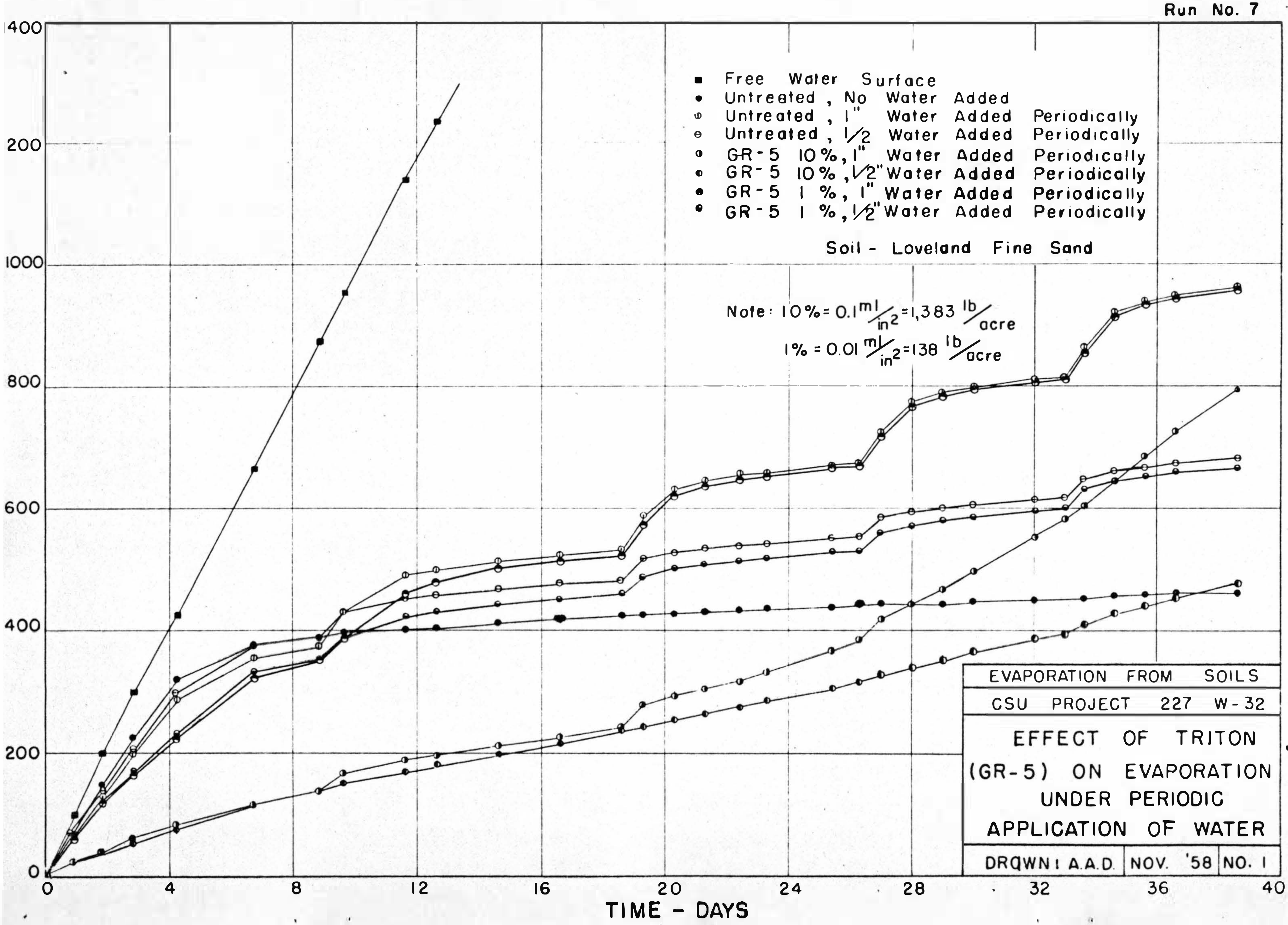
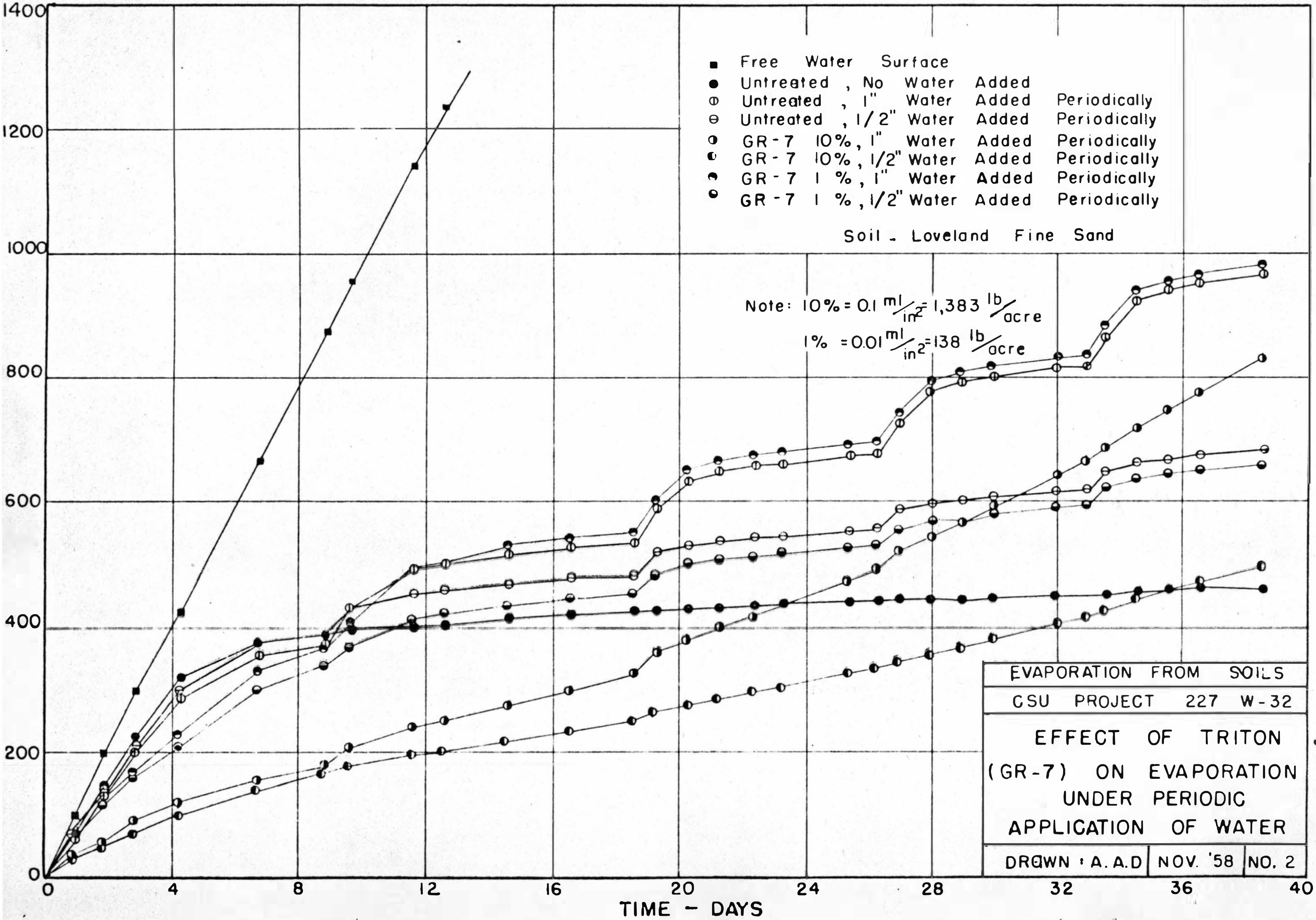

Run No. 7
Free Water Surface
Untreated , No Water Added
Untreated , 1" Water Added Periodically
Untreated , 1/2 Water Added Periodically
GR-5 10%, 1" Water Added Periodically
GR-5 10%, 1/2" Water Added Periodically
GR-5 1 %, 1" Water Added Periodically
GR-5 1 %, 1/2" Water Added Periodically
Soil - Loveland Fine Sand
Note: 10% = 0.1 ml/in² = 1,383 lb/acre
1% = 0.01 ml/in² = 138 lb/acre
0
200
400
600
800
1000
1200
1400
0
4
8
12
16
20
24
28
32
36
40
TIME - DAYS
EVAPORATION FROM SOILS
CSU PROJECT 227 W-32
EFFECT OF TRITON (GR-5) ON EVAPORATION UNDER PERIODIC APPLICATION OF WATER
DRAWN: A.A.D.
NOV. '58
NO. 1

Fig. 1

Run No. 7



EVAPORATION FROM SOILS		
CSU PROJECT 227 W-32		
EFFECT OF TRITON (GR-7) ON EVAPORATION UNDER PERIODIC APPLICATION OF WATER		
DRAWN : A.A.D	NOV. '58	NO. 2

Fig. 2

simulating conditions in the field on a summer day. The controls may be conveniently switched back to steady conditions.

The general design of the environmental-control chamber has been described in detail elsewhere (4). The air conditioning equipment is controlled by Barber-Colman proportioning electronic humidity and temperature controls. Both temperature and humidity sensing elements operate on a resistance-change principle, and are connected to separate bridge circuits. A change in resistance of a sensing element produces an unbalance in the bridge. Voltage from the unbalanced bridge is then amplified and used to actuate the appropriate corrective mechanism to produce the temperature and humidity changes required to bring the bridge circuits back into balance.

For any one setting of control point on the bridge circuits, the equipment maintains constant conditions of temperature and relative humidity in the environmental control chamber. In order to produce a cyclic variation of temperature and relative humidity, various amounts of resistance were added or removed on one leg of each bridge circuit at the proper times during the day. This was accomplished by using a timer which actuates a stepping relay* every 72 minutes or 1/20 of a day. A complete report of the details are in preparation.

For the cyclic variation of incident radiation, the appropiate points of the stepping relay were connected to relays located on the lamp bank, which in turn were connected to various lamps, thus, giving many possible combinations of lamps to produce the desired cyclic variation.

The cycles produced were of necessity step-wise approximations of a typical dirunal cycle. Figure 3 shows typical cycles for a summer day (1) and also the desired step-wise approximations.

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* C.P. Clare and Company, Chicago.

Figure 4 shows a typical hygrothermograph chart for one week of operation of the environmental-control chamber under cyclic conditions. The observed cyclic variations shown in Figure 4 are considered to be satisfactory approximations to the desired cycles shown in Figure 3.

With the chamber undergoing cyclic variation of ambient conditions, the studies of evaporation from soils in contact with a water table were resumed. The experimental apparatus shown in Figure 5. The soil column was placed in a 3 1/2-inch I.D. plastic cylinder with 1/4-inch wall thickness. Ice was maintained in the cooling chamber at the base of the column to keep the water entering the base of the soil column at a temperature from 60 - 75 °F. The soil column and cooling chamber were insulated with 1 1/2-inches of glass-wool insulation. A groove was cut around the inside of the plastic wall at the water supply inlet to facilitate the flushing of any entrapped air. This groove was contained in a plane making an angle of 30° with the horizontal. It was covered with a nylon screening material. The water-supply tap was also covered with nylon material. The other two manometers were tapped into a tensiometer ring (7) which consisted of a capillary barrier cemented over a groove which was machined around the inside wall of the plastic. The top tensiometer ring had a tap for flushing entrapped air. The water was supplied to the soil columns either from a large reservoir or from a volumetric burette used as a Mariotte Siphon. Thermocouples were located just beneath the surface of the soil and in the cooling chamber. Temperatures were measured by an arrangement for remote temperature recording in a manner described previously (5).

Manometers were read at irregular periods through the day. The soil columns were placed on a turntable to insure uniform exposure to ambient conditions. Data were taken on the drainage cycle.

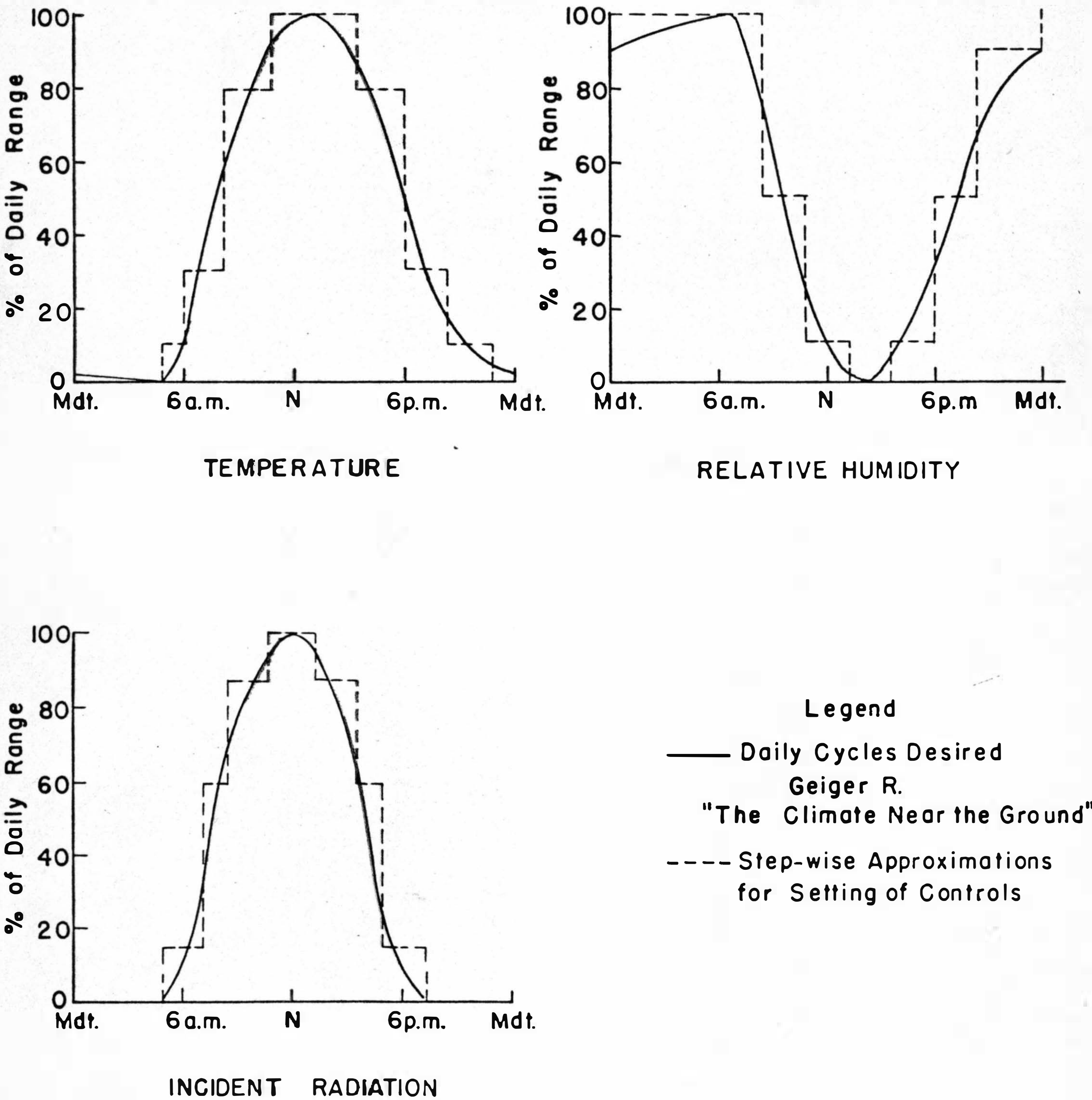

Fig. 3 Desired Diurnal Cycles of Ambient Conditions in Environmental Control Chamber

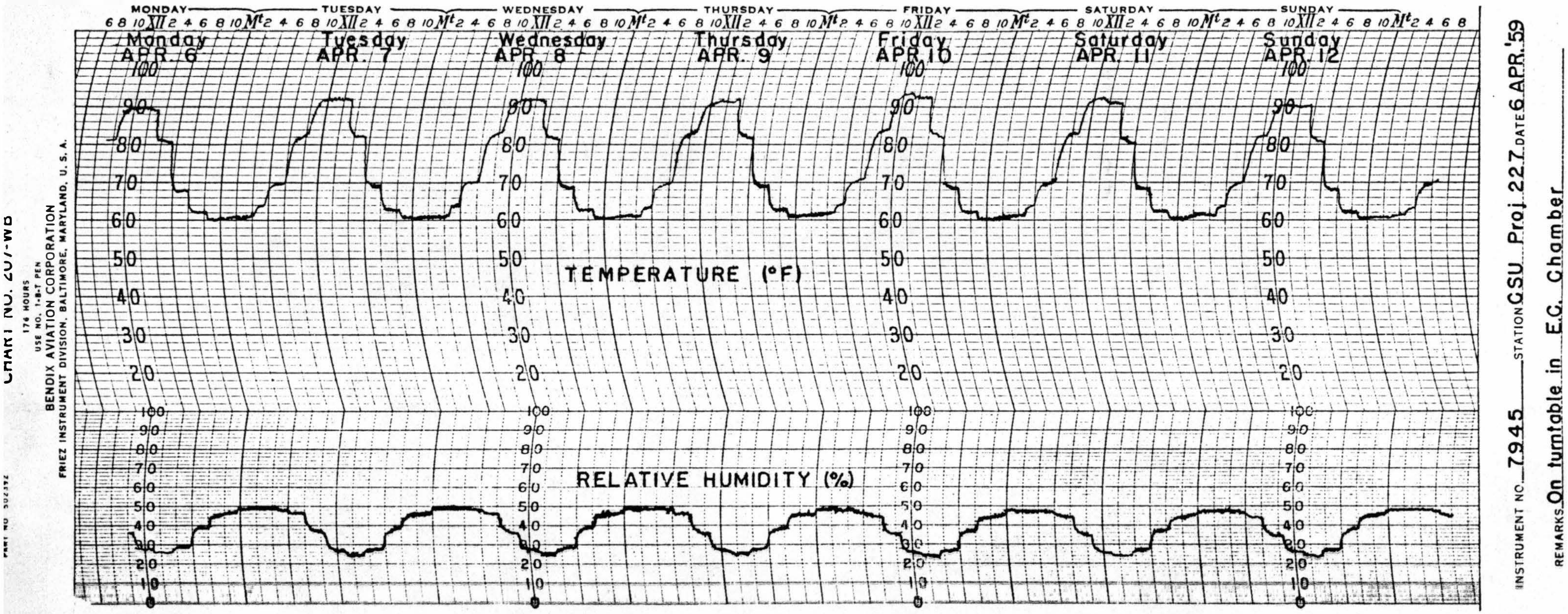

Fig. 4 Hygro-Thermograph Chart Showing Diurnal Cycles Produced in the Environmental Control Chamber

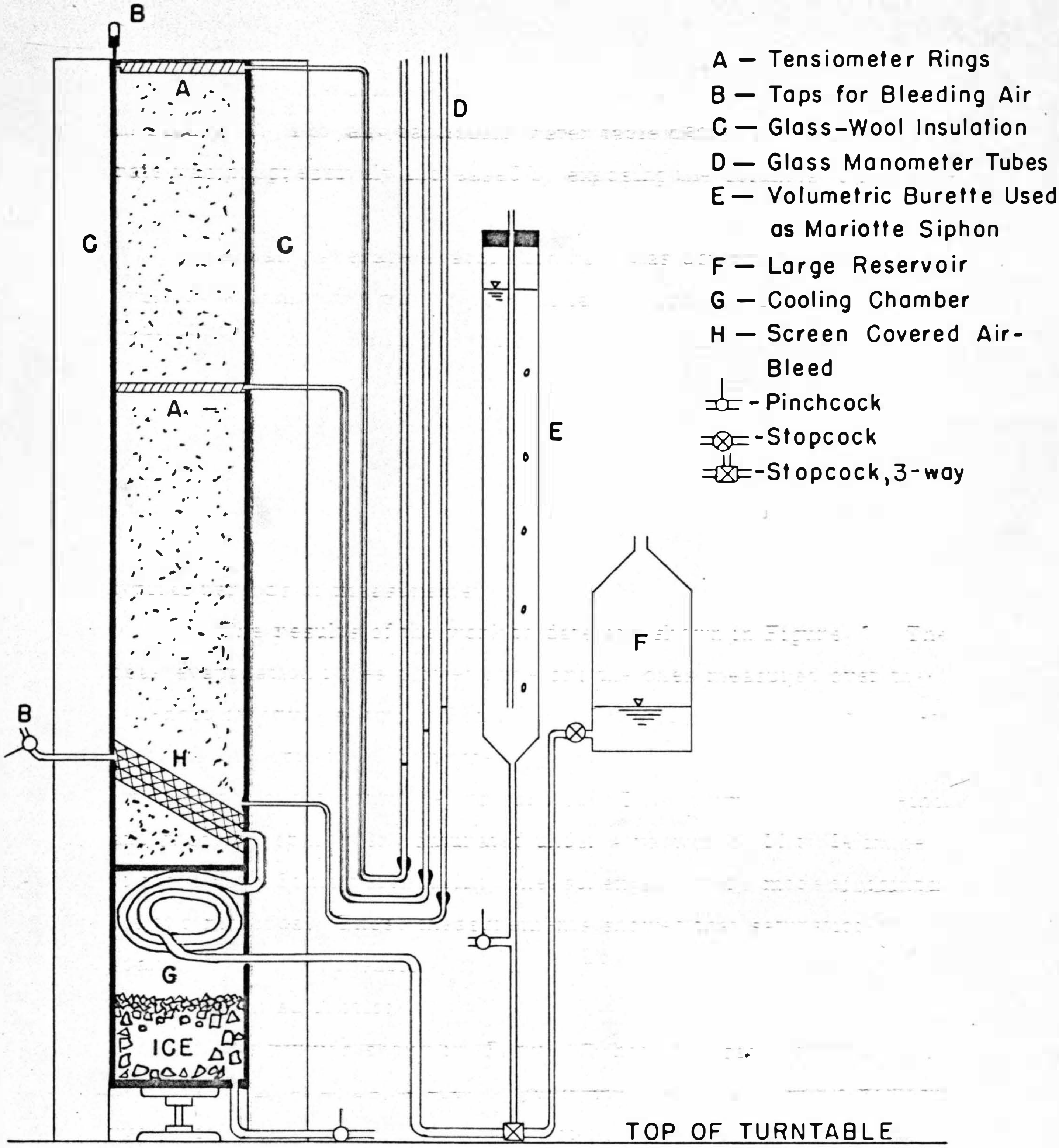

Fig. 5 Schematic Diagram of Evaporation Apparatus

Temperature and relative humidity followed the cyclic variation shown in Figure 4. For any particular water table depth, the evaporation rate was progressively increased by exposing the columns to increasing radiation.

A daily average evaporation rate was determined over an entire cycle by weighing the bottles used as large reservoirs. When the temperature was fairly constant at its highest value in the cycle, the supply was switched to the Mariotte Siphons and evaporation loss was measured volumetrically. Evaporation rates were determined over separate periods of 1.2 and 2.4 hours respectively during this peak of temperature. Figure 6 shows the variation with time of evaporation rate, ambient temperature, and soil surface temperature during typical periods of measurement.

The results of the work to date are shown in Figure 7. The peak evaporation rates plotted here are the ones measured over the 1.2-hour interval shown in Figure 6. The soil columns for the 12-inch water table depth were saturated initially by soaking in a vat and thus were probably not completely saturated. The columns for the 18-inch and greater depths were saturated under a vacuum of 23 to 24 inches of mercury. Some permeability measurements were made to compare the two methods. These measurements showed that saturation by soaking gave a permeability of only 60 per cent of the permeability after vacuum saturation.

The curves shown in Figure 7 have the same general form as those obtained under steady ambient conditions (2). For a particular water table depth, more severe evaporating conditions are necessary under cyclic ambient conditions than under steady ambient conditions in order to produce a reduction of e_s with increasing e_f. The reason

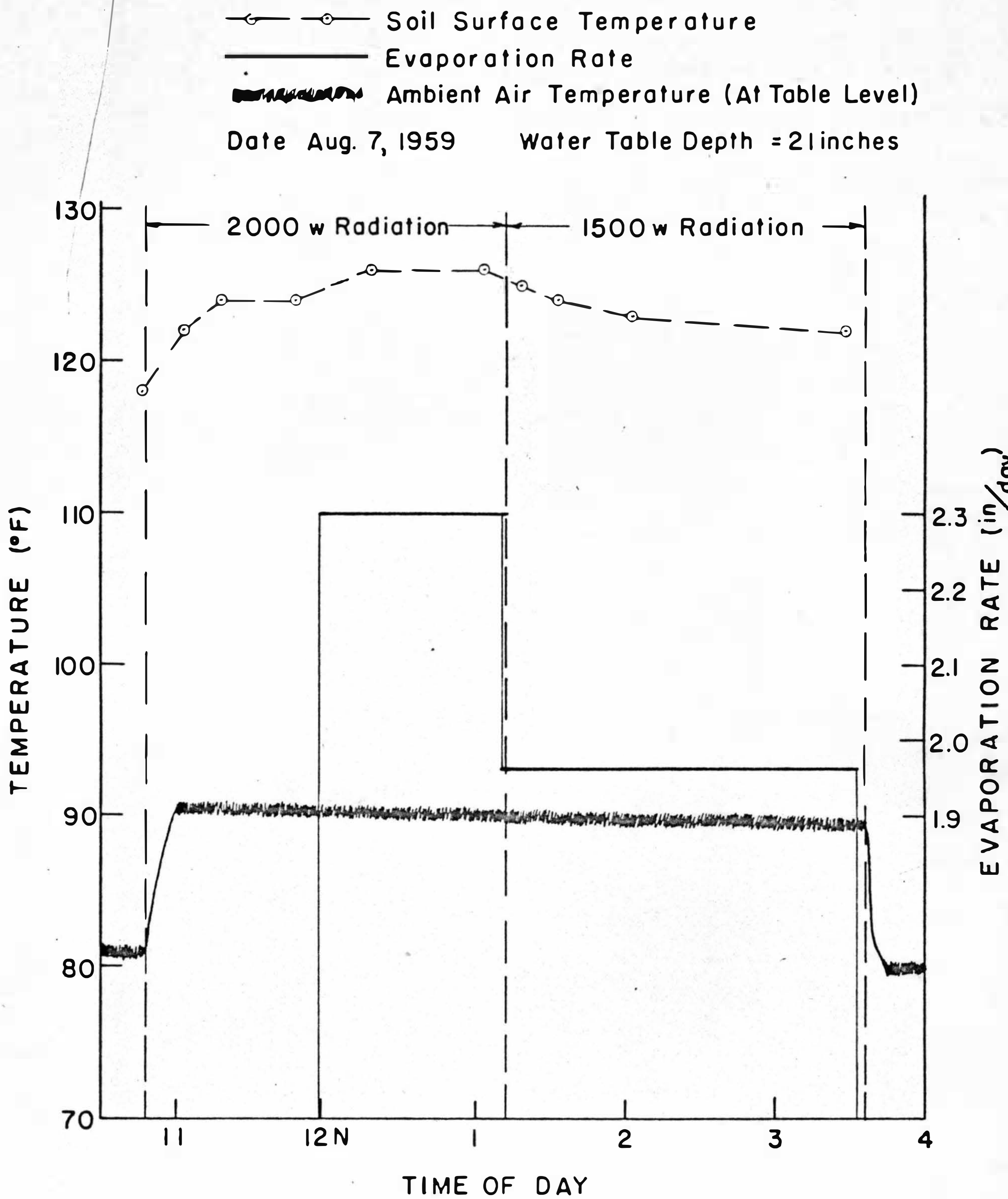

Fig. 6 Relation Between Soil Surface Temperature, Ambient Air Temperature, and Peak Evaporation Rate During Part of a Diurnal Cycle

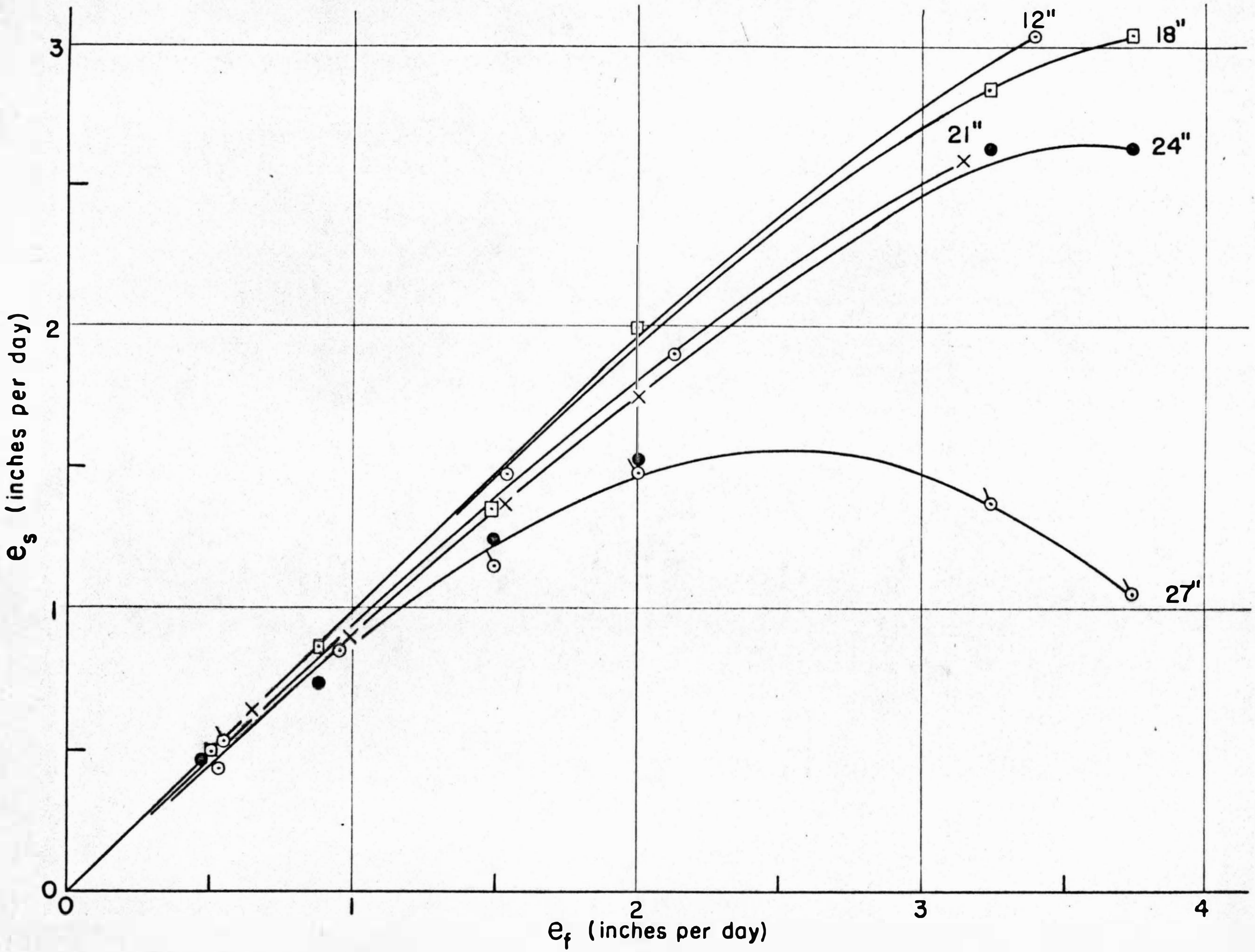

Fig. 7 Peak Evaporation Rates from a Fine Sand (e_s) as a Function of Peak Evaporation Rates from a Free Water Surface (e_f) and Depth of Water Table with Ambient Conditions Undergoing a Diurnal Cycle

for this is that the severe evaporating conditions are imposed on the soil for a shorter period of the total diurnal cycle. This indicates that the inverse relationship is probably less important as a natural mechanism for evaporation reduction under field conditions than might be expected from the laboratory work under steady conditions. However, if a layer of coarse particles could be maintained on the surface of a soil in the field, a significant reduction in evaporation could probably be realized.

Much effort has been directed toward the measurement of the capillary pressure of the water very near the surface of the soil. At a water table depth of 27" it was observed that with a peak rate of evaporation from the free water surface of 0.88 inches per day, the entire manometer tube, the lead, and the porvic ring at the surface of the column was completely drained of water by the end of the period of measurement of the peak evaporation rate. Because the lowest elevation of any part of the manometer was only 30 inches below the porvic ring, the maximum capillary pressure that the system was capable of measuring was 30 inches of water. The phenomenon described above indicates that the capillary pressure at the soil surface was greater than 30 inches of water for the fine sand under study when the inverse relationship occurred.

Plans for Future Experiments:

The present project is to be terminated June 30, 1960. During the remainder of this period, it is planned to continue the studies of evaporation from soils in contact with a water table under diurnal cyclic variation of ambient conditions. It is hoped to be able to determine how the relations established under steady ambient conditions might be modified to describe evaporation under the cyclic conditions. A method for accurate measurement of capillary pressure of the water very near the surface of the soil will be sought.

It is planned to investigate the possibility that the evaporation from a soil in contact with a water table may reach a stable value with increasing evaporativity after achieving the inverse relationship.

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